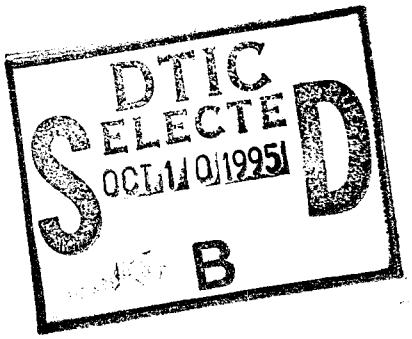
Technical Report EL-95-26
August 1995

US Army Corps of Engineers
Waterways Experiment Station

Analysis of Freshwater Mussels (Unionidae), Big Sunflower River Maintenance Project: 1993 Studies

by Andrew C. Miller, Barry S. Payne



Prepared for U.S. Army Engineer District, Vicksburg

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Waterways Experiment Station
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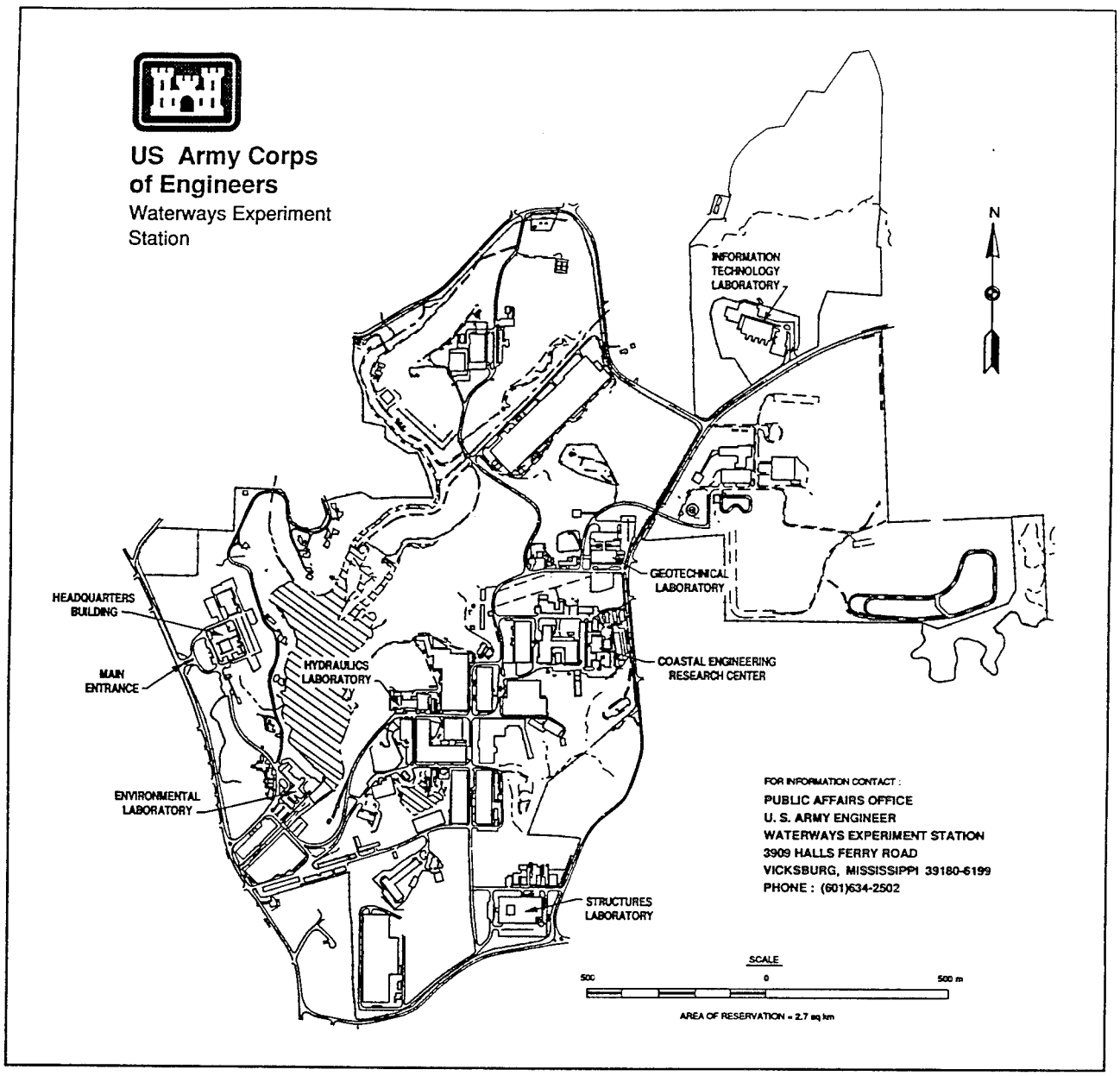

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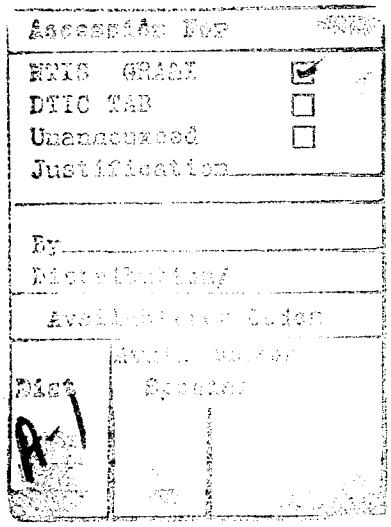

Preface

Research described in this report was conducted by the U.S. Army Engineer Waterways Experiment Station (WES) in the fall of 1993 for the U.S. Army Engineer District, Vicksburg, Vicksburg, MS. The purpose was to conduct a survey for freshwater bivalves (mussels in the family Unionidae as well as the nonindigenous Asian clam *Corbicula fluminea*) from selected reaches of the Big Sunflower River, Mississippi. Information obtained from the survey will be used by District personnel to analyze the environmental effects of dredging for the Big Sunflower River Maintenance Project.

Divers were Messrs. Larry Neill, Kevin Chalk, Robert T. James, Jeff Montgomery, and Pat Hjelm, Tennessee Valley Authority (TVA). Assistance in the field was provided by Mr. David Felder, Ms. Erica Hubertz, and Mr. Mark Farr, WES; Mr. Harvey Huffstatler, U.S. Fish and Wildlife Service; and Mr. Marvin Cannon, U.S. Army Engineer District, Vicksburg. Ms. Deborah Shafer, WES, was the Diving Inspector for this work. Figures were prepared by Ms. Sarah Wilkerson, Mississippi College, Clinton, MS, and tables were prepared by Ms. Geralline Wilkerson, Hinds Jr. College, Raymond, MS.

During the conduct of this study, Dr. John W. Keeley was Director, Environmental Laboratory (EL), WES; Dr. Conrad J. Kirby was Chief, Environmental Resources Division, EL, WES; and Dr. Edwin A. Theriot was Chief, Aquatic Habitat Group EL, WES. Safety equipment and foul weather gear were provided by TVA. Authors of this report were Drs. Andrew C. Miller and Barry S. Payne, WES. Drs. Miller and Payne designed the study and were responsible for all field and laboratory work.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. nautical)	1.852	kilometers
pounds (mass)	0.4535924	kilograms
tons (2,000 pounds, mass)	907.1847	kilograms

1 Introduction

Background

The U.S. Army Engineer District, Vicksburg, plans to dredge reaches of the Big and Little Sunflower Rivers, Mississippi, to improve flood conveyance and reduce local flooding. In the 1960s, snags were removed from much of the river, and a few short reaches were dredged. The proposed work will be accomplished mainly with a hydraulic dredge in order to minimize adverse environmental impacts. A commercial shell company recently determined that valuable stocks of freshwater mussels (Family: Unionidae) are in the Big Sunflower River. Preliminary estimates indicated that the potential value of these mussels could be very high. District personnel requested that a survey be conducted in these rivers to determine the extent, species composition, and density of mussels. This information will be used to determine the ecological and economic value of the resource and to develop methods to avoid and mitigate for dredging impacts.

Before the use of plastics, freshwater mussel shells were collected and used for the manufacture of pearl buttons (Coker 1919). Today, shells are used in the cultured pearl industry. They are cut into cubes, ground into spheres, and used as inserts for the production of cultured pearls. The increased demand during the past 3 to 5 years has pushed the price to about $6 per pound of shell on the Japanese market (Williams et al. 1993). The preferred stock is a thick, white shell free of blemishes from medium-size to large rivers in the United States. In 1991, the total tonnage exported to Japan was 9,000 short tons,[1] but demand has declined in the last 2 years and leveled to about 4,500 short tons (Baker, as cited by Williams et al. 1993). Concern over the spread of the exotic zebra mussel (*Dreissena polymorpha*) and its effects on native mussels could increase the demand and price for high-quality shell.

Freshwater mussels in Mississippi tend to be scattered and not found in discrete beds. Mussels are found in pools or runs stabilized by woody debris or aquatic macrophytes. As a result, most surveys in Mississippi have been qualitative, with investigators collecting live mussels or shells by hand.

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page vii.

Qualitative data on Mississippi bivalves have been obtained by Hinkley (1906), Frierson (1911), Isom and Yokley (1968), Grantham (1969), Stern (1976), Yokley (1979), Cooper and Johnson (1980), Hartfield and Rummel (1985), Hartfield and Ebert (1986), and Bogan, Hartfield, and Bogan (1987).

Prior to this study, there were two molluscan studies of the Big Sunflower River. Grantham (1969) recorded 13 species of mussels from the Yazoo Basin with only two (*Potamilus purpuratus* and *Amblema plicata plicata*) confirmed as occurring in the Big Sunflower River drainage. Miller, Payne, and Hartfield (1992) found a mussel bed near river mile (RM) 35.2 and used quantitative methods to collect 22 species of bivalves including the Asian clam *Corbicula fluminea*. No quantitative data on molluscan resources in the Big Sunflower River are available to document conditions prior to the 1960s.

Purpose and Scope

The purpose of this report is to present information on the location, species composition, density, and economic value of mussels in selected reaches of the Big and Little Sunflower Rivers that will be affected by the Big Sunflower Maintenance Project. This information will be used by District personnel to assess effects of proposed dredging and to develop strategies for reducing environmental effects of the project.

2 Study Area and Methods

Study Area

Study area. The Big Sunflower River originates in Moon Lake, Coahoma County, flows south through agricultural land and enters the Yazoo River between Sharkey and Yazoo Counties, Mississippi. The project area includes from its mouth to about RM 83 north of Cleveland, MS (Figures 1, 2, and 3). Although searches for mussels were made at multiple locations within the project area, intensive collecting was accomplished along specific reaches where dense populations were found.

Mussel collections were made at four beds downriver of Lock and Dam 1 (RM 62 - RM 33.7) and along a river reach upriver of the dam (RM 62.2 - RM 149.2). Downriver of the dam, the substratum at two beds consisted of sand and gravel; one was characterized by clay and sand; and one was composed of silt and sand. Shells of many specimens were eroded and difficult to identify. Upriver of the dam (RM 62.2 - RM 149.2), conditions were more depositional than downriver of the dam, and shells showed little evidence of erosion.

Collecting sites. In the reach downriver of Lock and Dam 1, intensive quantitative and qualitative collecting using divers was done only at high-density, discrete mussel beds located immediately upriver and downriver of the Holly Bluff Cutoff (Figure 1) and immediately downriver of Lock and Dam 1 (Figure 2). On 18 September 1993, collections were made by divers using qualitative methods at RMs 62.3, 66.0, and 73.8. Ten quantitative samples were taken at each of eight sites immediately downriver of the Holly Bluff Cutoff (quantitative sample numbers 3-7 and 15-17, Table 1). Mussels were collected from three sites (quantitative sample numbers 12-14) on a sand and gravel bar located at RM 35.2 upriver of the Holly Bluff Cutoff. This bar was sampled in 1987 (Miller, Payne, and Hartfield 1992a). Mussels were also collected at four sites (quantitative sample numbers 8-11) between RM 35.2 and the Holly Bluff Cutoff. Substratum consisted of hard-packed clay. Ten quantitative samples were taken at each of two sites (numbers 1 and 2) at RM 62.2 immediately downriver of abandoned Lock and Dam 1.

Upriver of abandoned Lock and Dam 1, mussels were only moderately dense and not found in discrete beds. A three-person (nondiver) crew collected mussels at 45 sites between RM 62.2 and RM 149.2 in October. Mussels were collected in water between 50 and 100 cm deep along either shore. Two sample methods were used. A 0.25-sq m quadrat was randomly placed in shallow water, and all live mussels encountered were removed. Three individuals each searched three quadrats, and nine quantitative samples were obtained at each site. In addition, each person searched the substratum by hand for 5 min (total collecting time at each site equaled 15 min).

Substratum conditions. Substratum at the mussel bed downriver of the Holly Bluff Cutoff consisted of more than 90 percent by weight of fine-grain particles less than 6.35 mm in diameter (Figure 4). Particles greater than 6.35 mm comprised less than 5 percent of the bed material. Substratum at the bed downriver of abandoned Lock and Dam No. 1 was characterized by a higher percentage of larger size material (Figure 5). Particles less than 6.35 mm in diameter comprised 60 to 70 percent and intermediate-size particles (6.35 to 34.0 mm) comprised less than 5 percent of the substratum. Large gravel and cobble (>34.0 mm) comprised 25 to 35 percent of the bed. The gravel bar upriver of the Holly Bluff Cutoff was characterized mainly by fine-grain sediments, which comprised 80 to 90 percent by weight of the bed material. Particles greater than 6.35 mm in diameter made up 15 to 20 percent of the substratum. Substratum between the Holly Bluff Cutoff and the gravel bar at RM 35.2 consisted of hard-packed clay.

Depositional conditions existed upriver of Lock and Dam 1. No extensive areas of sand and gravel were found. Fine-grain silt (diameters less than 6.35 mm in diameter) that was 50 to 70 cm deep was common along the shore.

Methods

Preliminary reconnaissance. A preliminary reconnaissance of the entire study area was conducted prior to initiating intensive sampling. On the first day of the survey, five two-person teams searched specific river reaches for mussels. Each team used a small boat and searched shallow areas along the shore and exposed bars for shells and live mussels. They obtained information on substratum conditions and water velocity. Field notes were recorded, and potential sites were marked on topographic maps. Detailed quantitative and qualitative samples would only be done at locations where mussels were present.

Qualitative mussel samples. Qualitative samples were obtained at promising sites by having three divers collect simultaneously. Each diver placed a specific number of live mussels in each of four nylon bags; 5 mussels were placed in one bag and 20 were placed in each of the other three bags. Divers were instructed to obtain mussels without bias toward size or type. They

attempted to exclude the Asiatic clam *Corbicula fluminea*. If *C. fluminea* was inadvertently collected, it was later eliminated. Divers collected using this method at the discrete mussel beds located upriver and downriver of the Holly Bluff Cutoff, as well as the bed downriver of abandoned Lock and Dam 1.

All mussels were brought to the surface, counted, and identified. Data were recorded on standard data sheets and returned to the laboratory for analysis and plotting. Shells of voucher specimens for each species were placed in plastic zipper lock bags and labeled with high rag content paper. Mussels not needed for voucher were returned to the river. Methods for sampling mussels are based on techniques described in Coker (1919); Brice and Lewis (1979); Miller and Nelson (1983); Isom and Gooch (1986); Kovalak, Dennis, and Bates (1986); Miller and Payne (1988); and Miller et al. (1993). Mussel identification was based on taxonomic keys and descriptive information in Murray and Leonard (1962), Parmalee (1967), Starrett (1971), and Burch (1975). Taxonomy is consistent with Williams et al. (1993).

Quantitative mussel samples. Divers obtained quantitative samples (that included unionids as well as *C. fluminea*) at beds upriver and downriver of the Holly Bluff Cutoff and downriver of abandoned Lock and Dam 1. At each mussel bed, two to eight sites were identified. At each site, 10 quantitative samples (0.25-sq m quadrats) were positioned approximately 1 m apart in a 2 by 5 matrix. All sand, gravel, shells, and live bivalves to a depth of 10 to 15 cm were excavated. Material was sent to the surface in a 20-L bucket and transported to shore. Sediment was screened through a series of three screens. All live mussels and *C. fluminea* removed from samples were placed in 4-L zipper lock bags. Each bivalve was then identified and total shell length (SL) measured to the nearest 0.1 mm with digital calipers. A subset of mussels was returned to the laboratory for morphometric analysis (measures of SL, height, and mass). Mussels identified and measured in the field were returned to the river unharmed.

Grain size analysis. Sediment samples from the quantitative samples from each wash screen were weighed on a top loading balance in the field. Mesh sizes of screens were 34.0, 12.7, and 6.35 mm. The sediments on each screen (excluding the mass of bivalves that were treated separately) were weighed in the field.

Data analysis. Species diversity was determined with the following formula:

$$H' = - p_j \log p_j$$

where p_j is the proportion of the population that is of the jth species (Shannon and Weaver 1949). Evenness was calculated with the modified Hill's ratio (Ludwig and Reynolds 1988). All calculations were done with programs written in BASIC or SAS (Statistical Analytical System) on a personal computer.

(1979) and Hurlbert (1984). Species area curves and dominance-diversity curves were constructed from qualitative and quantitative biological data. More information on methods used for this survey can be found in McNaughton and Wolf (1973); Isom and Gooch (1986); Kovalak, Dennis, and Bates (1986); Hughes (1986); Miller and Payne (1988), (1993), and (in preparation); and Miller et al. (1993).

Age-to-length relationships. Age-to-SL relationships for *Amblema p. plicata* were obtained by measuring the length to major external growth lines on the shell that were assumed to represent sustained periods of low growth during the winter (i.e., annuli in the sense often used in attempts to age mussels). A small subsample was used; individuals selected for counting were those in which annuli were particularly clear. Given both the small sample size and the narrow length range of *A. p. plicata* in the river, it was not appropriate to develop an age-to-length key.

3 Bivalve Community

Location of Important Mussel Resources

The mussel bed with the highest densities in the project area was located immediately downriver of abandoned Lock and Dam 1 (RM 62). This bed, which is located in an area scheduled for channel cleanout, was approximately 100 m long and 61 m wide. The bed reached across the channel, although the densest portion was along the left descending bank (LDB). A moderately high density bed was found immediately downriver of the Holly Bluff Cutoff (RM 34.7 to 33.7). Mussels were found almost completely across the 200-ft (61-m) channel. Mussels were also found immediately upriver of the Holly Bluff Cuttoff, RM 34.7 to RM 35.2. At the upper end of this reach was a stable sand and gravel bar that supported high densities of mussels. Mussels were found on both sides of the channel but were most dense along the LDB. Between the gravel bar and the Holly Bluff Cutoff, substratum consisted of hard-packed clay, and most of the mussels were along the LDB.

The reach of the Big Sunflower River between abandoned Lock and Dam 1 and approximately RM 150 supported moderately dense populations. High-density beds, such as were identified downriver of the lock and dam, were not found in this river reach. Densities were slightly higher between RM 62.2 and RM 83.0 than they were between RM 85.2 and RM 149.2.

Very low densities of mussels were found at the downriver portion of the Bogue Phalia River and Bogue Phalia Cutoff where these tributaries join the Big Sunflower River. Only scattered shells were found along the Bogue Phalia. This river does not appear to support a significant mussel resource. Only scattered shells and few live mussels were found along the Little Sunflower River.

It is likely that the majority of the freshwater mussels in the Big Sunflower River originated after the snagging that took place in the 1960s. Any mussels that were recruited prior to the 1960s would now be more than 30 years old. Although some species live to be 30 or more years old, it appears that most were recruited after the 1960s. Thin-shell species (*Anodonta* and *Leptodea*), as well as the small-sized *Truncilla* spp., typically live less than 10 years. However, these species were very uncommon in the river.

Proposed Channel Improvements

Background. Channel improvements were completed in the Big Sunflower River and its tributaries in the 1960s. That project included 47.48 miles of channel clearing, 21.5 miles of channel cleanout, 43.1 miles of channel enlargement, channel cutoffs aggregating 16 miles in channel length, and construction of eight weirs for the control of low water levels (U.S. Army Corps of Engineers, Hydrology and Hydraulics Appendix, 1993). Recent flooding in the lower reach of Bogue Phalia and Big Sunflower rivers in the past years necessitated a review of the river conditions. It was determined that the channel had deteriorated since completion of the earlier project. Channel maintenance was recommended for the following reaches:

River	Affected Reach, RM
Big Sunflower	6.9 to 75.6
Big Sunflower Bend	19.2 to 33.5
Little Sunflower	7.0 to 27.7
Bogue Phalia	0.0 to 24.2
Bogue Phalia Cutoff	0.0 to 12.4
Dowling Bayou	3.7 to 8.0

Proposed actions for the Big Sunflower River were designed to return conditions to those created by completion of the 1960 project. Typical actions are illustrated in Figures 6 and 7. The following reaches will be affected:

River Mile	Type of Improvement
0.0 - 6.9	No Work[1]
6.9 - 19.2	Channel Cleanout - 3 ft - 85 ft width
19.2 - 26.1	Channel Cleanout - 80 ft bottom[2]
26.1 - 26.4	Channel Cleanout - 200 ft bottom[2]
26.4 - 26.6	No Work[3]
26.6 - 28.4	Channel Cleanout - 200 ft bottom[2]
28.4 - 37.9	No Work[4]
37.9 - 49.6	Channel Cleanout - 3 ft - 250 ft width
49.6 - 50.2	No Work[4]
50.2 - 53.9	Channel Cleanout - 3 ft - 250 ft width
53.9 - 54.1	No Work[3]
54.1 - 57.5	Channel Cleanout - 3 ft - 250 ft width
57.5 - 70.6	Channel Cleanout - 3 ft - 250 ft width
70.6 - 75.6	Channel Cleanout - 3 ft - 150 ft width

[1] No flow in this reach - diverted through Six Mile Cutoff.
[2] Restoration of channel to authorized bottom width and grade.
[3] No work reach to avoid high-density mussel bed.
[4] Sufficient channel capacity.

The Holly Bluff Cutoff (from RM 19.3 to RM 26.1) will be cleaned with a dragline to a width of 80 ft. Information from Bogue Phalia River and Cutoff have not been included since actions proposed for those areas should not have a major effect on mussels.

Bivalves Downriver of Lock and Dam 1

Bivalve community characteristics. A total of 27 species of bivalves, including the Asian clam *Corbicula fluminea*, were collected during the survey of the Big Sunflower River (Table 2). Eighteen and twelve species were taken in qualitative and quantitative samples, respectively, downriver of abandoned Lock and Dam No. 1. Upriver of Lock and Dam 1, 23 species were found.

Based upon qualitative collections at the four beds, the fauna was strongly dominated by the commercially valuable threeridge (*Amblema plicata plicata*), which comprised 68 percent of the fauna (Appendix A, Table A1). The bank-climber (*Plectomerus dombeyanus*) was about one-third as common and comprised approximately 19 percent of the fauna. Four thick-shell species (two species of *Quadrula*, *Obliquaria reflexa*, and the commercially valuable washboard, *Megalonaias nervosa*) each comprised from 1 to 6 percent of the assemblage. Eleven species each comprised less than 1 percent of the fauna. The majority of these mussels are thick-shell and commonly collected in medium-size to large rivers in the central United States. Only three thin-shell species, *Leptodea fragilis*, *Pyganodon grandis*, and *Utterbackia imbecillis* were collected (Appendix A, Table A2). *Pleurobema pyramidatum*, a candidate species for listing as endangered, was found in beds upriver and downriver of Lock and Dam 1. Overall, it comprised 1.7 percent of the mussel assemblage.

Amblema plicata plicata was taken in over 98 percent of the samples, and *P. dombeyanus* was found in nearly 70 percent of the samples at these beds. The other 15 species were taken in 50 percent or less of the samples.

A plot of species rank versus percent abundance and occurrence, Figure 8, illustrates data presented in Appendix A. The extreme dominance of one species (*A. p. plicata*) is depicted, especially at the bed located immediately downriver of Lock and Dam No. 1. Species are more evenly distributed in the other three mussel beds than at the bed downriver of Lock and Dam 1. The species in these assemblages spans two or three orders of magnitude.

The relationship between cumulative number of species versus the cumulative number of individuals collected provides an indication of the amount of effort required to collect uncommon species (Figure 9). Using qualitative methods, 15 species were identified at sites downriver of Holly Bluff Cutoff after 1,000 individuals had been collected. Collecting another 2,000 individuals at the other beds yielded another 2 species for a total of 17.

Density. Mean density of bivalves at the four beds ranged from 28.6 $\pm$ 2.8 ($\pm$Standard Error of the Mean) to 235.0 $\pm$ 16.0 individuals/sq m (Table 3).

Density was significantly different among all mussel beds ($F = 196.7$, $p < 0.001$). The within-bed variation in density was significant ($p < 0.05$) at all beds with the exception of the gravel bar upriver of the Holly Bluff Cutoff (Table 4). The high density at the mussel bed downriver of Lock and Dam 1 as compared with the other beds is illustrated in Figure 10. The significant within-bed variation at the bed downriver of the Holly Bluff Cutoff is illustrated in Figure 11.

Mean biomass (wet weight in grams/square meter) was high and variable at these beds and directly related in numerical density (Tables 3, 4 and Figures 10, 11). Biomass ranged from 6,590.8 $\pm$ 636.1 to 52,250 $\pm$ 3,284.8 g/sq m at the four mussel beds. Biomass was approximately five times greater at the bed immediately downriver of Lock and Dam 1 than at the other beds.

Amblema plicata plicata dominated the quantitative samples and ranged from a low of 49 to a high of 90 percent of the fauna at the four mussel beds (Appendix B). Either *Q. p. pustulosa* or *P. dombeyanus* was the second most abundant in these quantitative samples, although in either case these species were usually less than half as common as *A. p. plicata*. The species area curve for quantitative samples (Figure 9, bottom) increased at about the same rate as the curve for qualitative samples (Figure 9, top). Both methods yield about the same number of species per sampling effort. After slightly more than 1,000 individuals had been collected, 15 species were identified, regardless of method.

Mussels collected in the bed immediately upriver of Holly Bluff Cutoff were highly eroded. Low-calcium content water and the erosive action of sand and gravel had detrimental effects on the shells.

Bivalves Upriver of Lock and Dam 1

Community characteristics. Two survey methods were used upriver of Lock and Dam 1. In September, divers and nondivers collected using qualitative methods at three locations (RMs 62.2, 66.0, and 73.8) upriver of Lock and Dam 1. Divers searched for specific time periods at 1.5- and 1.8-m depths, and nondivers collected at sites 0.6 and 0.6 to 1.2 m deep along the shore. A total of 1,537 bivalves were collected (Appendix C, Tables C1-C4). During October and November, nondivers collected along the shore (in water less than 1 m deep) at 45 sites located between RM 62.2 and RM 149.2. A total of 25 species (5 more than were taken at beds downriver of Lock and Dam 1) were found (Table 2).

In the reach upriver of Lock and Dam 1, mussel distribution was related to depth. *Plectomerus dombeyanus* dominated in shallow water along the shore (Tables C1-C4 and Figure 12). At RM 62.3, *P. dombeyanus* comprised about 70 percent of the fauna in water 0.6 m deep. This species was absent or

uncommon in water deeper than 1.5 m. *Quadrula pustulosa pustulosa* and *M. nervosa* tended to be more common in deeper water than along the shore.

In October and November, nondivers collected a total of 23 species and 2,941 individuals (Appendix D, Tables D1-D3). At shallow-water sites along the shore, total individuals ranged from 0 to 236 and species ranged from 0 to 12. No live bivalves were collected at only 2 of the 45 sites. The fauna was dominated by *P. dombeyanus* and *A. p. plicata*, which comprised 57 and 21 percent of the assemblage, respectively (Table D3). As noted above, *P. dombeyanus* tended to be most common in shallow water. Had sampling been conducted in deeper water, fewer numbers of this species would have been collected. Seven species comprised 1 to 5 percent, and 14 species comprised less than 1 percent of the assemblage (Table D3).

Bivalve density ranged from 0 to 25.3, and collecting rate ranged from 0 to 16.2/min at shallow-water sites between RM 62.2 and RM 83.0 (Table D4, Figure 13). Mussel density decreased moving upriver. Between RM 85.2 and RM 149.2, density and collecting rate were approximately 50 percent of the downriver reach. The relationship between density and collecting rate was weak; the correlation coefficient was 0.71 (Figure 14).

The rate at which bivalves were collected is listed for divers and nondivers in Tables C1-C4 and D4-D5. Collection rates varied from 1.3 to 8.9/min at sites located at RMs 62.3, 66.0, and 73.8 that were sampled mainly by divers (Appendix C). Collection rate ranged from 0.0 to 16.2/min at 45 shallow-water sites sampled by nondivers located upriver of Lock and Dam 1. These collection rates can be used to compare various sites within the project area and are not necessarily an indication of the amount of commercially valuable shell that can be collected per unit time. Divers for this survey were instructed to search the substratum for mussels without bias toward species and size. Commercial shell collectors, who have an obvious incentive for retrieving certain species quickly, could produce different results.

Size Demography of Dominant Populations

Amblema plicata plicata. The size structure of *A. p. plicata* was remarkably uniform at all locations (Figures 15-18). With a single exception, mussels ranged in length from 72 to 108 mm. The exception was a single mussel measuring 59 mm in length that was sampled from the gravel bar above the Holly Bluff Cutoff (Figure 16). Otherwise, the population throughout the Sunflower River was comprised only of large mussels having modal length of 86 to 96 mm.

Plectomerus dombeyanus. The size structure of this species was remarkably uniform at all sites (Figures 19-22). All populations were comprised of relatively large and old individuals. Individuals measuring 55 and 75 mm in length were collected below Holly Bluff Cutoff (Figure 22); otherwise, no

mussels less than 82 mm long were collected. Most individuals measured from 90 to 110 mm in length.

Quadrula pustulosa pustulosa. This species was collected in sufficient abundance for demographic analysis below Lock and Dam 1 (Figure 23), at the gravel bar above Holly Bluff Cutoff (Figure 24), and below Holly Bluff Cutoff (Figure 25). Only a single recent recruit was collected; this individual measured 25 mm and was obtained below Holly Bluff Cutoff (Figure 25). Most individuals measured from 50 to 60 mm long at all three locations; downriver of Lock and Dam 1, there were considerably more very large mussels (60 to 80 mm) than at the other two mussel beds.

Megalonaias nervosa. This species was collected in sufficient numbers to support demographic analysis at sites above and below Holly Bluff Cutoff. As with other species and sites, there was no evidence of significant intersite variation in size demography or of substantial recent recruitment (Figures 26-27). Most individuals at both sites ranged from 100 to 150 mm in length. The smallest mussels at either site (89 and 93 mm) were still moderately large.

Presence of Uncommon, Threatened or Endangered Species

No Federally listed threatened or endangered species were found in the project area (U.S. Fish and Wildlife Service 1993). Species found in the project area that are not commonly taken in southern streams include *Lampsilis hydiana, Uniomerus declivis, U. tetralasmus,* and *Pleurobema pyramidatum. Pleurobema pyramidatum* is a candidate species for the Federal list of endangered species and is considered by the State of Mississippi as endangered. Other species that were very uncommon in the project area but are typically collected in rivers in the south and midwest are *Tritogonia verrucosa, Truncilla donaciformis,* and *T. truncata.*

4 Economic Value of Mussels in Big Sunflower River

Marketable Species and Sizes

The commercial shell industry typically purchases only thick-shell species for use as pearl inserts. In addition to a thick shell, the nacre should be white and free of blemishes. Although many species are potentially marketable (i.e., *Quadrula* spp., *Fusconaia* spp., and *Pleurobema* spp.), usually the threeridge (*A. p. plicata*) and washboard (*M. nervosa*) comprise the majority of the market. In the Big Sunflower River, these two species will dominate commercial sales. The bank climber (*Plectomerus dombeyanus*) is abundant although not marketable.

Size limits for freshwater mussels are based on the minimum dimension or shell height. If a live specimen cannot pass through a metal ring of a given diameter, then it is considered legal. In scientific surveys, total SL is typically measured and used to determine length-weight or length-age relationships. In this survey, SL of each specimen collected was measured using quantitative methods. Shell height, dry shell mass, and total wet mass of a subset of commercially valuable species were also measured.

A specimen of *A. p. plicata* from the Big Sunflower River that is 100 mm long has a height of approximately 69.8 mm (Figure 29). *Megalonaias nervosa* from the Big Sunflower River of the same length has a height of about 71.8 mm (Figure 30). A 100-mm-long *A. p. plicata* has a total mass (live weight) of 183.9 g (Figure 29) and a total shell mass of about 80 percent less or 146.9 g (Figure 31). *Megalonaias nervosa* that is 100 mm long has a total mass (live) of 195.0 g (Figure 30) and a shell mass that is 62 percent less or 121.3 g (Figure 31).

In four states bordering the upper Mississippi River, the minimum marketable size limit for *A. p. plicata* is 2.75 in. (69.8 mm). The minimum size for *M. nervosa* is 4.0 in. (101.6 mm). The minimum shell heights in Wisconsin waters for *A. p. plicata* is 2.63 in. (66.8 mm) (Thiel and Fritz 1993).

Although there is an effort to standardize all harvesting regulations in upper Mississippi River waters, in practice this has not taken place. In Indiana, the size limit is 2.5 in. (63.5 mm) for all species except 15 listed as endangered (Anderson, Stefanavage, and Flatt 1993). In 1952 in Kentucky, a minimum size limit of 2.5 in. was established for all shells (Crowell and Kinman 1993). In 1987, regulations were changed to 3.75 in. (95.2 mm) for *M. nervosa* and 2.75 in. for *A. p. plicata.*

In February 1994, the Mississippi Department of Wildlife, Fisheries, and Parks tentatively established minimum sizes for marketable shells in the Big Sunflower River. The minimum marketable size of *A. p. plicata* (threeridge) was set at 2-5/8 in. high. The minimum size of *M. nervosa* (washboard) will be 3.25 in. high in 1994 and 4.0 in. high in 1995. There is an advantage for harvesters to have the shell sizes as small as possible. However, a small-size shell, especially one with ridges, will be less marketable than larger shells. The larger shells potentially provide a larger number of inserts than smaller ones. Tables 5 and 6 give SLs in millimeters that correspond to these shell heights in inches.

Percent Abundances of Selected Sizes of Commercially Valuable Species

As an aid to determining the economic value of commercially valuable species in the Sunflower River, *A. p. plicata* and *M. nervosa* from all sites were grouped, and size demography was plotted by shell height in English Units (Figures 32 and 33). Shell heights were determined from length-weight relationships (Figures 29 and 30). Each shell height unit on the X axis includes all sizes halfway between the previous and next size grouping. For example, 15.65 percent of the *A. p. plicata* in the Big Sunflower River have a shell height between 2.475 and 2.525 in. If the minimum marketable size of the threeridge was 2.5 in. high (equal to about 89 mm long), then 66.78 percent of the existing resource would be available for harvest (i.e., have shell heights greater than 2.50 in.) (Table 5, Figure 32). If the minimum marketable size of *M. nervosa* in the Big Sunflower River was 3.75 in. (equal to about 136 mm long), then approximately 30 percent of the existing population could be harvested (Table 6, Figure 33).

Length-frequency histograms for *M. nervosa* and *A. p. plicata* from Pool 10 of the upper Mississippi River have been included for comparison (Figures 34 and 35, respectively). Approximately 9 percent of the threeridge population depicted in Figure 35 have a SL greater than 87.6 mm. This value is equivalent to a shell height of 2.63 in. or 66.8 mm, the marketable size in Wisconsin waters (Thiel and Fritz 1993). Larger size mussels were in the population taken from the lower Tennessee River in 1990 than were collected in the Sunflower River or the upper Mississippi River (Figure 36). However, only 4.38 percent of that population would be marketable, based on length-height relationships and regulations pertaining to the upper Mississippi River.

The shape of the threeridge in the Big Sunflower River differs from specimens in the upper Mississippi River. For organisms of a similar SL, the specimens from the Big Sunflower River are comparatively less high than specimens from the upper Mississippi River. A 100-mm long *A. p. plicata* in the upper Mississippi River has a shell height of approximately 75.6 mm. A threeridge of similar length taken from the Sunflower River has a height of only 69.8 mm. Shell length and shell height plots for this species from the Big Sunflower River (Figure 29) can be contrasted with specimens from Pool 10 of the upper Mississippi River (Figure 37). Regression equations for *A. p. plicata* at these two locations are as follows:

Big Sunflower River: SH = 0.57*SL + 12.46
Upper Mississippi River: SH = 0.71*SL + 4.54

The higher slope for specimens in the upper Mississippi River reflects a comparatively higher shell height than those from the Big Sunflower River.

A subset of *A. p. plicata* was obtained for age to SL determinations (Figure 38). Specimens that are 2.50 in. high (and 89 mm long) were estimated to be 19 years old.

An Estimate of Commercial Value of Mussels in Project Area

The above information was used to estimate the commercial value of the threeridge and washboard in the project area (Table 7). The following assumptions were made:

a. Marketable sizes (shell height) of the threeridge and washboard were estimated at 2-5/8 (2.625) in. (66.67 mm) and 3.25 in. (82.55 mm) high, respectively. Average total organism weight was estimated based on these sizes and length-weight relationships for the Big Sunflower River (Figures 29 and 30). The average mass of *A. p. plicata* greater than 66.67 mm high (Table 5) was 168.07 g. The percentage of the resource that was marketable, taken from Figure 32, was 36 percent. The average mass of *M. nervosa* greater than 82.55 mm high (Table 6) was 438.81 g. The percent marketable, from Figure 33, was 84.427 percent. These values could be altered if decisions regarding marketable size in the project area change.

b. The price per pound (total live weight) was estimated to be $1.00. This value could be adjusted as needed.

c. The above estimates are based on population structure and density determined in the fall of 1993. New recruits will become marketable through time, and this value could be determined. It was estimated that a marketable-size threeridge grows approximately 2 mm per year (Figure 38).

d. Sizes of the four mussel beds (one immediately downriver of Lock and Dam 1, one immediately downriver of the Holly Bluff Cutoff, and two immediately upriver of the Holly Bluff Cutoff) are based on measurements made in the field.

e. It was assumed that mussels were found in virtually all of the river between Lock and Dam 1 and the upriver extent of the project area, RM 83. Live mussels were found at every site searched between these two river miles (Appendix D). An average density was applied to shallow- and deep-water sites, and the percent composition of the two commercially valuable species was based on survey results. The small area actually searched versus the total amount available (26 sites in more than 20 miles) makes accurate estimations difficult. Additional work could improve these estimates.

f. It was determined that the most dense concentrations of mussels were in four distinct beds downriver of Lock and Dam 1. However, shells and live specimens were found outside of these mussel beds. It is possible that harvestable populations may be found outside of these beds.

Based upon the above assumptions, it was determined that 1.39 and 1.34 million pounds of threeridge and washboard are in the project area. At a price of $1 per pound, these two species would have a total value of approximately $2.7 million dollars (Table 7).

5 Discussion

Characteristics of Bivalve Community

Community characteristics. Total bivalve species richness in the study area (27 species including the Asian clam *C. fluminea*), based on quantitative and qualitative methods (Table 2), is similar to or perhaps slightly greater than that at other mussel beds in large rivers. At a bed in the lower Ohio River near Olmsted, IL, 23 species of freshwater mussels were identified. In a survey of the lower Tennessee River, Miller, Payne, and Tippit (1992) collected 4,768 individuals and identified 23 species. The total number of species in the East Channel of the upper Mississippi River supports is 30 (Miller and Payne, in preparation).

The unionid fauna of most large rivers is dominated by two or three species. At a bed in the middle Ohio River near Cincinnati, the fauna was dominated by *Pleurobema cordatum* and *Q. p. pustulosa*, which together comprised 39.9 percent of the assemblage (Miller and Payne 1993). At a bed in the lower Tennessee River, the fauna was dominated by *A. p. plicata* (39.4 percent) and *Fusconaia ebena* (39.4 percent) (Miller, Payne, and Hartfield 1992). The Big Sunflower River is unusual in that most reaches are heavily dominated by a single species, *A. p. plicata*. At the bed immediately downriver of Lock and Dam 1, *A. p. plicata* comprised 90 percent of the fauna. The next most common species was *Q. p. pustulosa* (3.5 percent) (Table B7).

Extreme dominance by a single species depressed species diversity values (H′). At the site below Lock and Dam 1, H′ was 0.49. Species diversity ranged up to 1.46 at the other beds surveyed using quantitative methods. Simpson's dominance, which ranges from near 0 to near 1.0 (for a community dominated by a single species) equaled 0.81 at the bed immediately downriver of Lock and Dam 1 (Table B7).

Density. Mean unionid density at the four beds (28.6 $\pm$ 2.8 to 235 $\pm$ 16.0 individuals/sq m, Table 3) is greater than that reported by other workers in medium- to large-size rivers in the United States. In the lower Tennessee River (RM 22.2 to RM 21.2), Miller, Payne, and Tippit (1992) estimated total density to range from 9.2 to 128.0 individuals/sq m at six closely placed sites (10 quadrats collected at each). At an inshore and offshore site sampled in

1986 at RM 18.6 in the lower Tennessee River (32 quantitative samples were collected at each), total mussel density was 187.7 and 79.7 individuals/sq m, respectively (Way, Miller, and Payne 1989). In the middle Ohio River near Cincinnati, mussel density ranged from 4.4 to 52.4 individuals/sq m (Miller and Payne 1993).

Size demography. There was essentially no evidence of substantial inter-site variation in size demography of assemblages sampled at different beds throughout the Sunflower River. All populations were characterized by very little or no recent recruitment. Comparison of *A. p. plicata* samples from the present study (Figures 15 to 18) to samples collected in 1987 from the gravel bar just above the Holly Bluff Cutoff (Figure 28) revealed only slight change in the size structure of this population. Mussels greater than 98 mm in length were considerably more abundant (25 percent) in 1987 than they were in the present study (8 percent).

Evidence of recent recruitment. The number of individuals less than 30 mm total SL provides an estimate of the amount of recent recruitment. Individuals of this size would be approximately 2 to 3 years old, and their presence would indicate that conditions were appropriate for successful recent reproduction. The percentage of individuals less than 30 mm total SL ranged from 0.0 at the bed immediately downriver of Lock and Dam 1 to 0.35 percent at sites immediately downriver of the Holly Bluff Cutoff (Tables B1, B3, B5, and B7). As length-frequency histograms from the study area illustrated (Figures 15-28), small-size individuals were virtually absent for dominant species of freshwater mussels.

The lack of recent recruitment in the Big Sunflower River is difficult to explain with only 2 years of detailed study, 1993 and 1987 (Miller, Payne, and Hartfield 1992). Successful recruitment requires the presence of appropriate fish hosts (Fuller 1974) as well as proper water quality, velocity, and temperature. It is possible that there have been several periods of recruitment since the Big Sunflower River was dredged in the 1960s. However, as the various individuals grow, they probably become virtually indistinguishable in the length-frequency histograms plotted for each species.

At a mussel bed in the lower Ohio River, a single cohort of *F. ebena* with an average SL of 15.8 mm represented 71 percent of the population (Payne and Miller 1989). Several years passed before strong recruitment for this species was noted. At a bed in the middle Ohio River, *F. ebena* in this size category comprised about 20 percent of the population (Miller and Payne 1993). Successful stocks of freshwater mussels (and other long-lived species) can be sustained without annual recruitment.

Summary. The four beds in the Big Sunflower River were characterized by high density and often extreme dominance by a single species (*A. p. plicata)*. Typically, there was little or no evidence of recent recruitment. It is likely that all of the living mussels in the river have been recruited since channel maintenance in the 1960s. The lack of small specimens was noted in

high-density areas (greater than 200 individuals/sq m) as well as low-density areas (5 to 10 individuals/sq m). It appears unlikely that high-density populations are inhibiting recruitment since no recruitment was found upriver of Lock and Dam 1 where densities were low. Shells of the commercially valuable threeridge have a larger length:height ratio than specimens from a bed in the upper Mississippi River. Upriver of Lock and Dam 1, specimens exhibited little evidence of erosion and appeared to be of moderate-to-high quality. At beds immediately upriver of the Holly Bluff Cutoff, shells were highly eroded and often difficult to identify.

It is difficult to determine why mussels have achieved extremely high densities in a few portions of the river, yet exhibit so little evidence of recent recruitment. In comparison with habitats in northern latitudes, these mussels could be stressed by elevated temperatures in the summer, low calcium content water, and high sediment deposits. Although these effects are obviously negative, they do not appear to have affected the ability of these areas to support high-density populations.

Protecting Mussels in Project Area

Impacts of dredging. Removal of mussels from the river bottom, using either a hydraulic dredge or dragline, and transporting them to an upland disposal site would result in 100-percent mortality. If dredged material is deposited in the water, it is likely that a very small percentage of mussels would survive. Most mussels have the ability to extricate themselves after being buried, as long as sediments are not more than a few centimeters deep. However, there is the likelihood that high mortality will result from dredging operations. Mussels can be negatively affected by the effects of elevated suspended solids immediately downriver of a dredge. However, the molluscan gill and feeding palps are designed to separate nutritious particles from inorganic particles with no food value. In addition, mussels in the project area have adapted to a naturally high suspended sediment regimen. Because of the uncertainty of these estimates, the effects of elevated suspended sediments from dredging on mortality have not been determined.

As illustrated in Figures 6 and 7, the dredging will take place in the center of the river channel. Mussels along the bank will not be physically disturbed. However, they could be affected by increased sedimentation from the dredging. However, they represent a stock that could potentially provide new recruitment.

Effects of commercial shell harvest. A commercial shell harvester using scuba or surface supplied air has the potential for removing virtually all mussels from a bed. A brail (a series of hooks that snag mussels) misses many individuals and can be less detrimental to valuable beds. However, an experienced shell diver should take only commercially valuable species. Uncommon or rare species with no commercial value should be left in the river. If unmarketable mussels are collected, they should be returned to the river, not

dumped on shore. In addition, when size limits are placed on the population, not all specimens will be collected. Most mussels that have been temporarily removed from the substratum (especially the fine-grained sediment in the project area) have the ability to dig back in and should survive.

Commercial shell harvest has the potential to be detrimental to mussel resources. However, if carefully regulated, reproducing populations can be maintained. If collectors and buyers can recognize and do not disturb uncommon or endangered species, then a rich community can be sustained.

Recommendations. With careful planning, mussels in the Big Sunflower River could survive selective harvest and some disruption from dredging. The following recommendations are made:

a. Size limits and species composition of the commercial harvest should be carefully monitored to ensure that uncommon or very rare species are not taken. Small-size, commercially valuable species should be a source of future populations and should not be harvested.

b. Selected areas should be set aside as a sanctuary where no harvesting would be permitted. This would provide an undisturbed community for future reproduction as well as a control (no commercial impact) for future study. At a minimum, a reach upriver of Lock and Dam 1 and a bed near the Holly Bluff Cutoff should be excluded from harvest. Actual sizes of these sanctuary areas have not been established. However, a linear distance of 1 to 2 km or more would be reasonable.

c. For the reach of river upriver of Lock and Dam 1, every effort should be made to restrict dredging and associated impacts to the main channel as planned. This would protect the mussels along the bank and could provide a source of future recruitment.

d. Every effort should be made to reduce the effects of dredging at the mussel bed immediately downriver of Lock and Dam 1 and immediately upriver and downriver of the Holly Bluff Cutoff. Some mussels would survive if dredging took place only on one side of the river.

e. The effects of dredging and commercial harvest should be monitored. Quantitative and qualitative methods should be used to collect mussels in the areas where commercial harvesting is permitted and where dredging took place. Information should also be obtained from nondredged areas and reaches where harvest is prohibited. Required information should include data on density, community composition, evidence of recruitment, and population structure, as well as shell morphometrics (SL to shell height and SL to shell mass and total shell mass). These findings will be used to assist with regulating the commercial harvest and can be used to assess the environmental effects of maintenance dredging.

Summary. Maintenance dredging and commercial shell harvest could negatively affect common and uncommon species. The lack of recent recruitment, dominance of a single species, and low species richness make this community particularly vulnerable. Upriver of the dam, dredging should be restricted to the channel to protect valuable populations along the shore. The beds downriver of the dam could be partially protected by restricting dredging to one river bank. Commercial harvest should be carefully regulated and monitored, and selected reaches should be set aside as sanctuaries. The long-term survival of this resource could be ensured by regular monitoring and careful adherence to well-designed dredging and commercial harvest plans.

References

Anderson, R. M., Stefanavage, T., and Flatt, T. (1993). "Why did Indiana halt commercial mussel harvest?" *Conservation and management of freshwater mussels.* K. S. Cummings, A. C. Buchanan, and L. M. Koch, ed., Proceedings of a UMRCC Symposium, 14-19.

Bogan, A. E., Hartfield, P. D., and Bogan, C. M. (1987). "The unionid fauna of the eastern tributaries of the Mississippi River (Mollusca: Bivalvia: Unionidae)." *American Malacological Union 53rd Annual Meeting Abstracts.*

Brice, J., and Lewis, R. (1979). "Mapping of mussel (Unionidae) communities in large streams," *The American Midland Naturalist* 101, 454-455.

Burch, J. B. (1975). *Freshwater Unionacean clams (Mollusca: Pelecypoda) of North America.* Malacological Publications, Hamburg, MI.

Coker, R. E. (1919). "Fresh-water mussels and mussel industries of the United States," *Bulletin of the United States Bureau of Fisheries* 13, 75-181.

Cooper, C. M., and Johnson, V. W. (1980). "Bivalve mollusca of the Yalobusha River, Mississippi," *The Nautilus* 94, 22-24.

Crowell, E. F., and Kinman, B. J. (1993). "Musseling in Kentucky: The first 200 Years." *Conservation and management of freshwater mussels.* K. S. Cummings, A. C. Buchanan, and L. M. Koch, ed., Proceedings of a UMRCC Symposium, October 1993.

Frierson, L. S. (1911). "A comparison of the unionidae of the Pearl and Sabine rivers," *The Nautilus* 24, 134-136.

Fuller, S. L. H. (1974). "Clams and Mussels (Mollusca: Bivalvia)," *Pollution ecology of fresh water invertebrates.* C. Hart and S. L. H. Fuller, ed., Academic Press, New York, 215-273.

Grantham, B. J. (1969). "The fresh-water pelecypod fauna of Mississippi," Ph.D. diss., University of Southern Mississippi, Hattiesburg, MS.

Green, R. H. (1979). *Sampling design and statistical methods for environmental biologists*. Wiley, New York.

Hinkley, A. A. (1906). "Some shells of Mississippi and Alabama," *The Nautilus* 20, 40-45.

Hughes, R. G. (1986). "Theories and models of species abundance," *The American Naturalist* 128, 879-899.

Hurlbert, S. H. (1984). "Pseudoreplication and the design of ecological field experiments," *Ecological Monographs* 54, 187-211.

Isom, B. G., and Gooch, C. (1986). "Rationale and sampling design for fresh-water mussels, unionidae, in streams, large rivers, impoundments, and lakes." *Rationale for sampling and interpretation of ecological data in the assessment of freshwater ecosystems*. ASTM STP 894, B. G. Isom, ed., American Society for Testing and Materials, Philadelphia, PA, 46-59.

Isom, B. G., and Yokley, P., Jr. (1968). "Mussels of Bear Creek Watershed, Alabama and Mississippi, with a discussion of area geology," *American Midland Naturalist* 79, 189-196.

Kovalak, W. P., Dennis, S. D., and Bates, J. M. (1986). "Sampling effort required to find rare species of freshwater mussels." *Rationale for sampling and interpretation of ecological data in the assessment of freshwater ecosystems*. ASTM STP 894, B. G. Isom, ed., American Society for Testing and Materials, Philadelphia, PA, 34-45.

Ludwig, J. A., and Reynolds, J. F. (1988). "Statistical ecology." *A primer on methods and computing*. Wiley, New York.

McNaughton, S. J., and Wolf, L. L. (1973). *General ecology*. Holt, Rinehart, and Winston, Inc., New York.

Miller, A. C., and Nelson, D. A. (1983). "An instruction report on fresh-water mussels," Instruction Report EL-83-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, A. C., and Payne, B. S. (1988). "The need for quantitative sampling to characterize size demography and density of freshwater mussel communities," *American Malacological Bulletin* 6, 49-54.

Miller, A. C., and Payne, B. S. (1993). "Qualitative versus quantitative sampling to evaluate population and community characteristics at a large-river mussel bed," *The American Midland Naturalist* 130, 133-145.

_____. "Effects of increased commercial navigation traffic on freshwater mussels in the upper Mississippi River: 1992 studies" Technical Report in preparation, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, A. C., Payne, B. S., and Hartfield, P. D. (1992). "Characterization of a dense mussel bed in the Big Sunflower River, Mississippi," *Journal of the Mississippi Academy of Sciences* 37(3), 8-11.

Miller, A. C., Payne, B. S., Shafer, D. S., and Neill, L. T. (1993). "Techniques for monitoring bivalve communities and populations in large rivers." *Conservation and management of freshwater mussels.* K. S. Cummings, A. C. Buchanan, and L. M. Koch, ed., Proceedings of a UMRCC Symposium, 147-158.

Miller, A. C., Payne, B. S., and Tippit, R. (1992). "Characterization of a freshwater mussel community immediately downriver of Kentucky Lock and Dam in the Tennessee River," *Transactions of the Kentucky Academy of Sciences* 53(3-4), 154-161.

Murray, H. D., and Leonard, A. B. (1962). *Handbook of Unionid mussels in Kansas.* Museum of Natural History, University of Kansas, Lawrence, KS.

Parmalee, P. W. (1967). "The fresh-water mussels of Illinois," *Illinois State Museum Popular Science Series* 8, 1-108.

Payne, B. S., and Miller, A. C. (1989). "Growth and survival of recent recruits to a population of *Fusconaia ebena* (Bivalvia: Unionidae) in the lower Ohio River," *The American Midland Naturalist* 121, 99-104.

Shannon, C. E., and Weaver, W. (1949). *The mathematical theory of communication.* University of Illinois Press, Urbana, IL.

Starrett, W. C. (1971). "A survey of the mussels (Unionidae) of the Illinois River: A polluted stream," *Illinois Natural History Survey Bulletin* 30(5), 266-403.

Stern, E. M. (1976). "The freshwater mussels (Unionidae) of the Lake Maurepas-Ponchartrain-Borgne drainage system, Louisiana and Mississippi," *Dissertation Abstracts International (B)* 37(5).

Thiel, P. A., and Fritz, A. W. (1993). "Mussel harvest and regulations in the upper Mississippi River system." *Conservation and management of freshwater mussels.* K. S. Cummings, A. C. Buchanan, and L. M. Koch, ed., Proceedings of a UMRCC Symposium, 11-18.

U.S. Army Engineer District, Vicksburg. (1993). "Hydrology and hydraulics appendix, Supplement D to GDM No 1 for the Big Sunflower River Maintenance Project," Vicksburg, MS.

U.S. Fish and Wildlife Service. (1991). Endangered and threatened wildlife and plants. *Federal Register*, July 15, 1991. 50 CFR 17.11 & 17.12.

Way, C. M., Miller, A. C., and Payne, B. S. (1989). "The influence of physical factors on the distribution and abundance of freshwater mussels (Bivalvia: Unionidae) in the lower Tennessee River," *The Nautilus* 103, 96-96.

Williams, J. D., Warren, M. L., Jr., Cummins, K. S., Harris, J. L., and Neves, R. J. (1993). "Conservation status of freshwater mussels of the United States and Canada," *Fisheries* 18(9), 6-22.

Yokley, P., Jr. (1979). "A survey of the bivalve mollusks of the Buttahatchie River, Alabama and Mississippi," Third Supplemental Environmental Report, Volume VIII, Appendix D, U.S. Army Corps of Engineers, Mobile, AL.

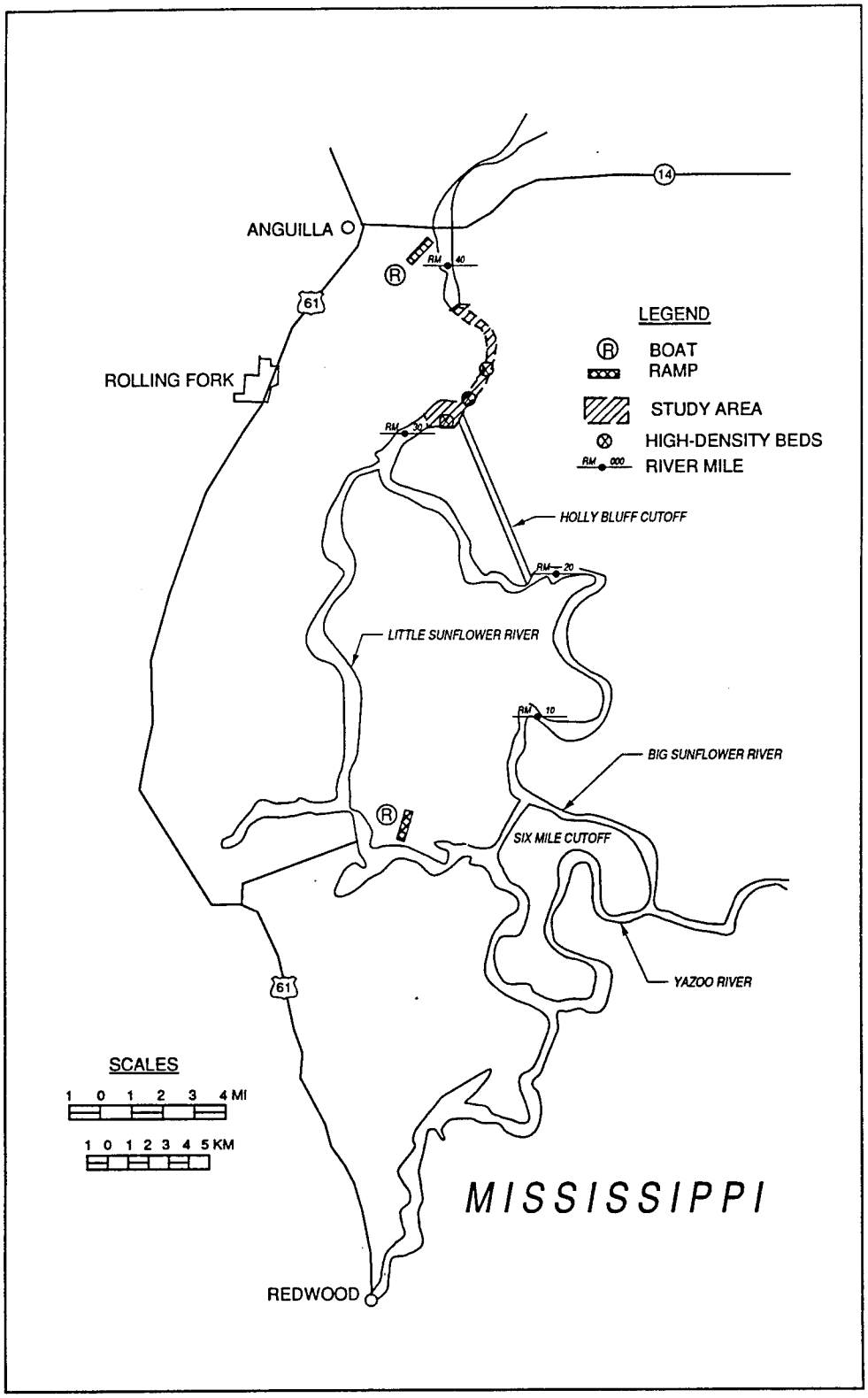


Figure 1. Most downriver section of study area is illustrated. Intensive collections were made at mussel beds located immediately upriver and downriver of Holly Bluff Cutoff

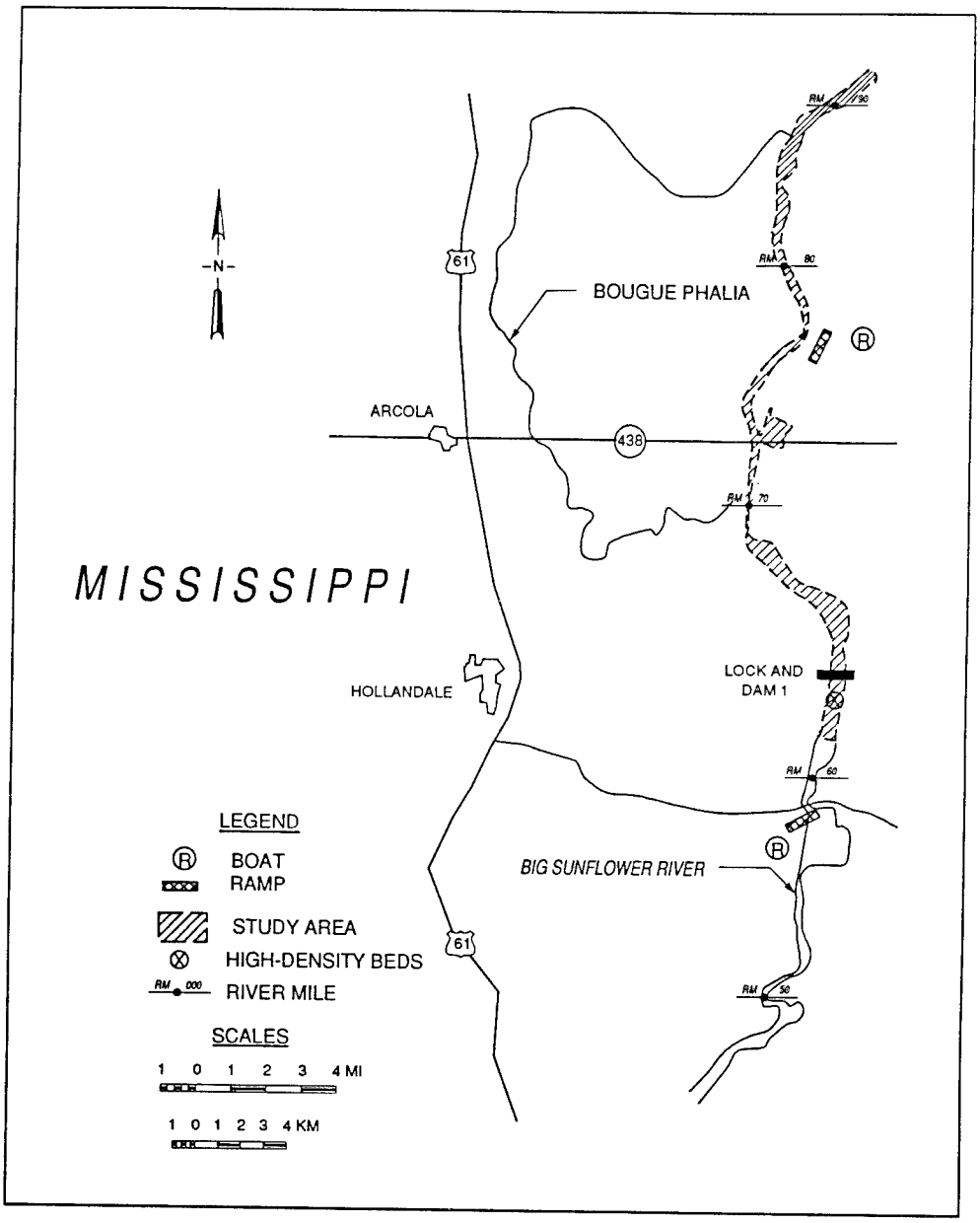


Figure 2. Central portion of study area is depicted. Intensive collections were made immediately downriver of abandoned Lock and Dam 1 and at multiple sites upriver of dam

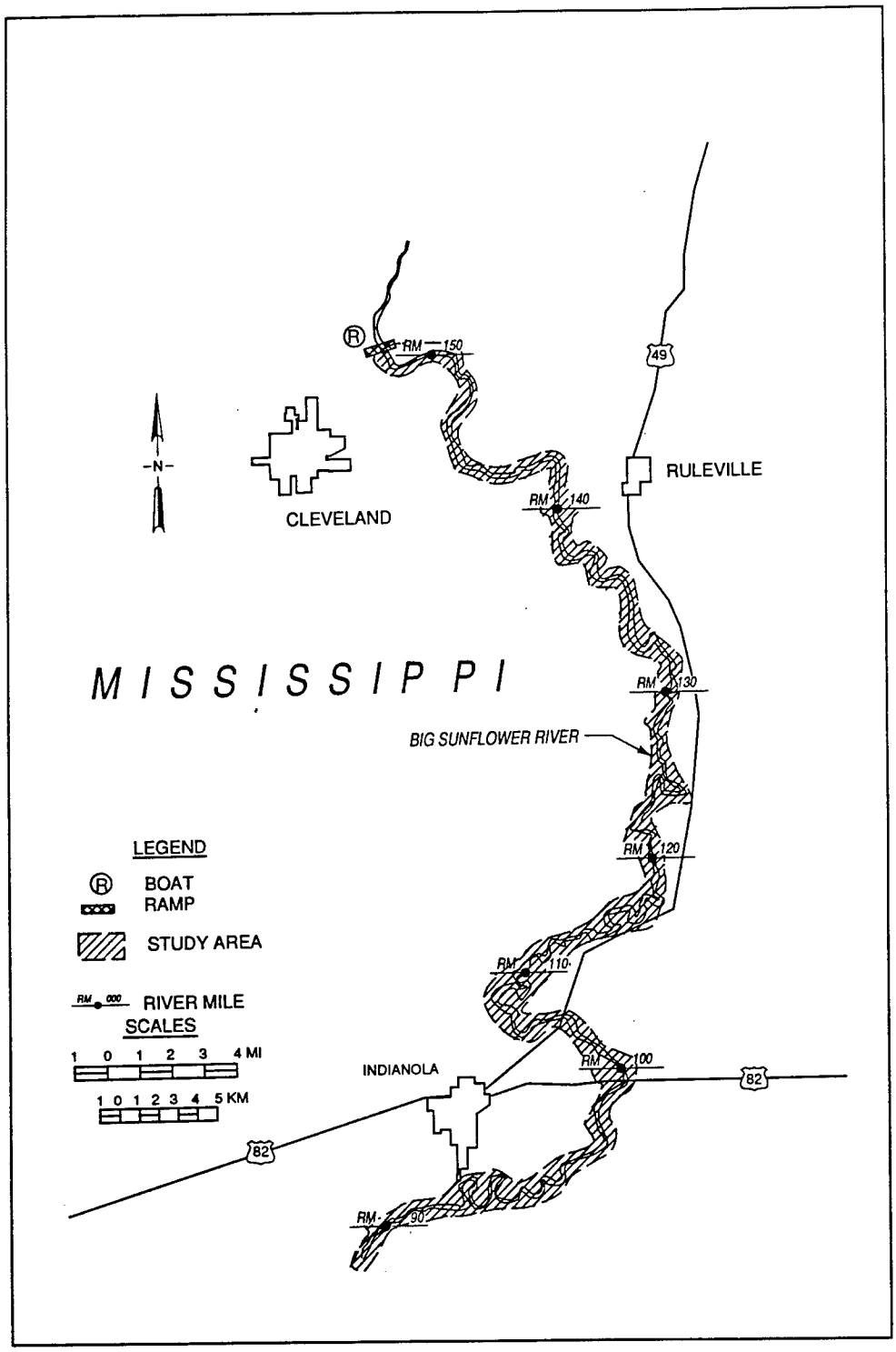


Figure 3. Upriver section of study area is illustrated. Qualitative and quantitative methods were used to collect mussels in shallow water (<1 m deep) between RM 90 and RM 150. Divers collected at deepwater sites upriver of Lock and Dam 1 on 18 September 1993

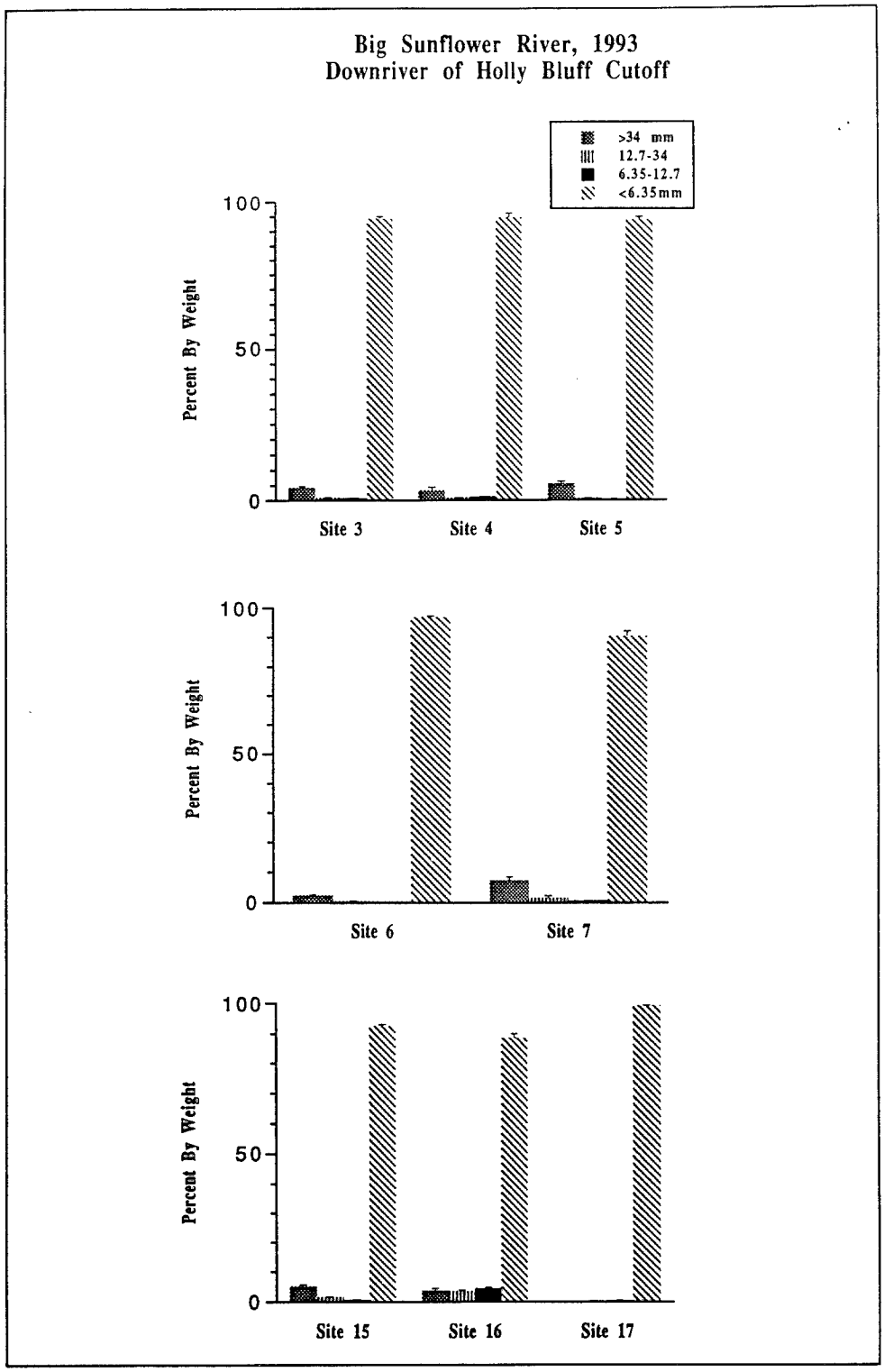


Figure 4. Grain size analysis, determined in field, at seven sites on a mussel bed immediately downriver of Holly Bluff Cutoff

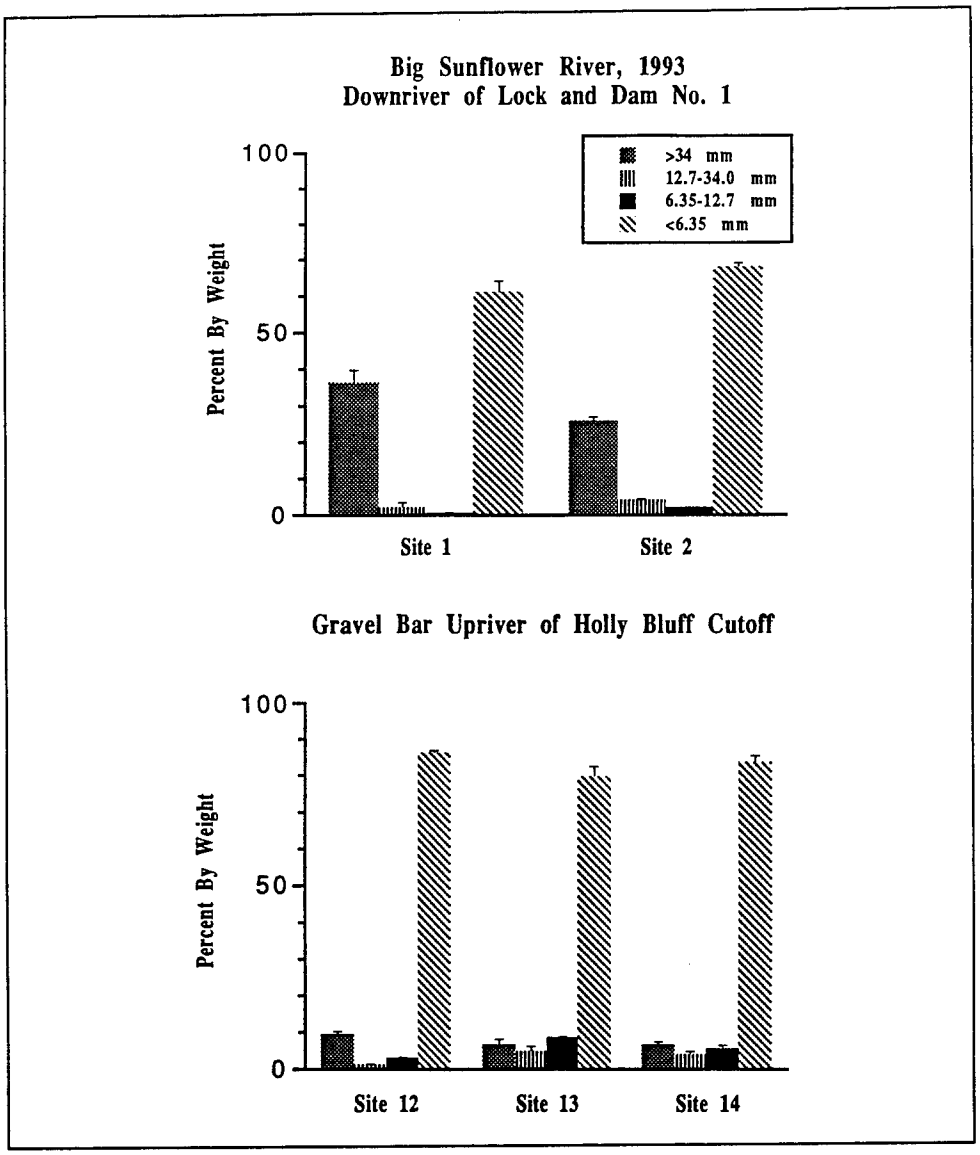


Figure 5. Grain size analysis, determined in field, at two sites on a bed immediately downriver of Lock and Dam 1 and three sites at a gravel bar immediately upriver of Holly Bluff Cutoff

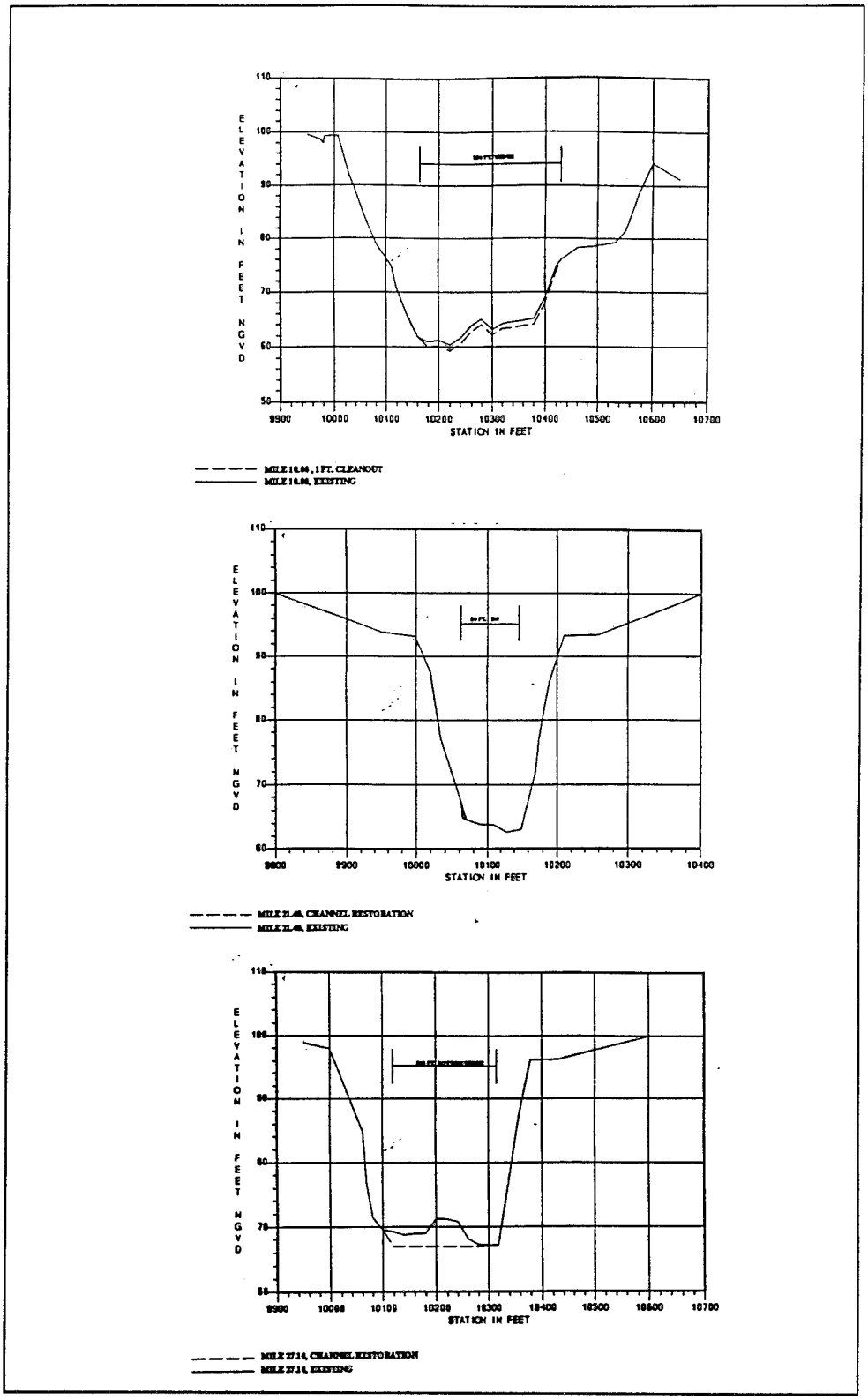


Figure 6. Typical cross-sectional maintenance at selected reaches of Big Sunflower River (taken from Hydrology and Hydraulics Appendix, Supplement D to GDM 1 (U.S. Army Engineer District, Vicksburg 1993))

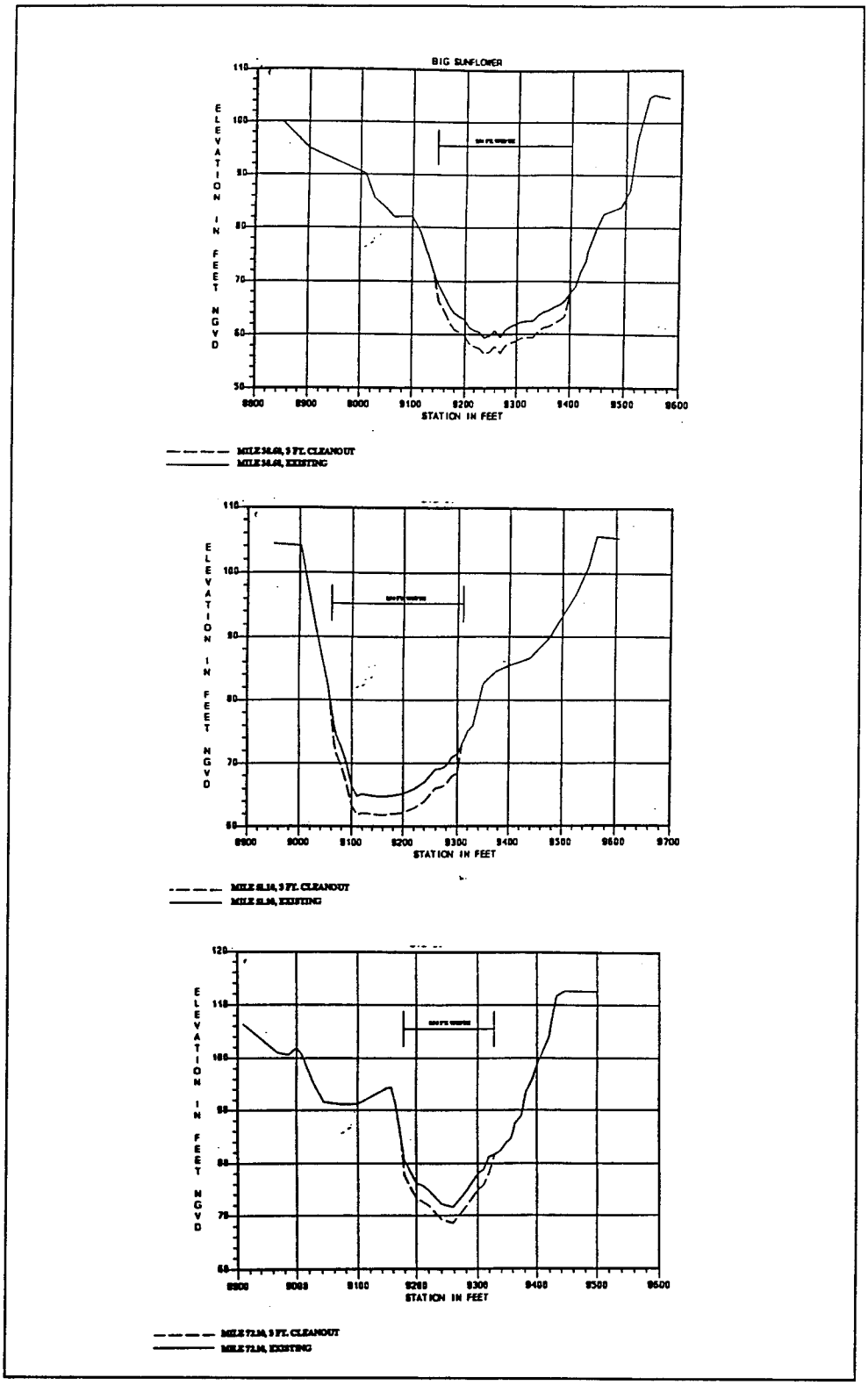


Figure 7. Typical cross-sectional maintenance at selected reaches of Big Sunflower River (taken from Hydrology and Hydraulics Appendix, Supplement D to GDM 1 (U.S. Army Engineer District, Vicksburg 1993))

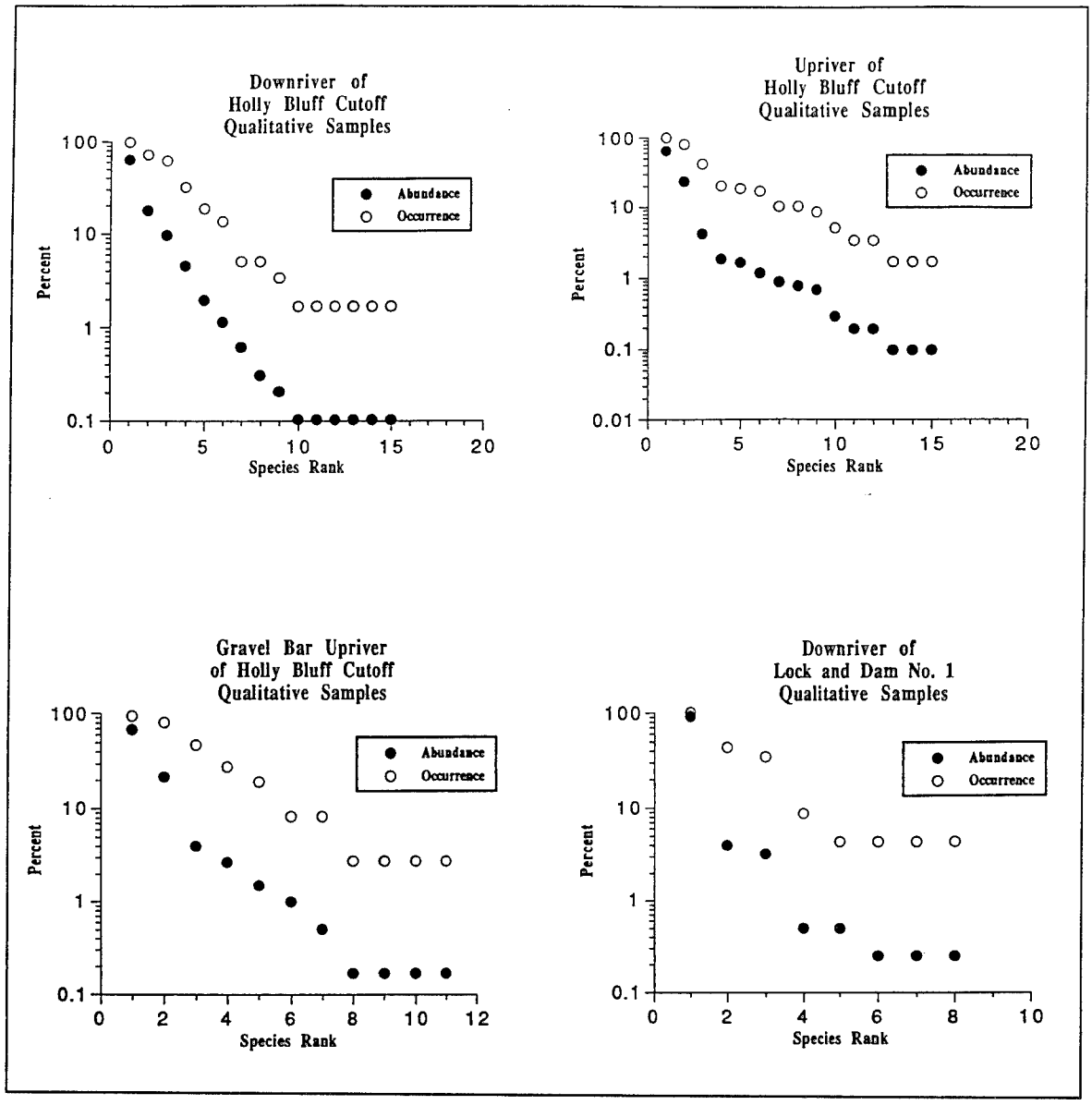


Figure 8. Species rank versus percent abundance and percent occurrence of freshwater mussels, based on qualitative collections, at four locations in Big Sunflower River

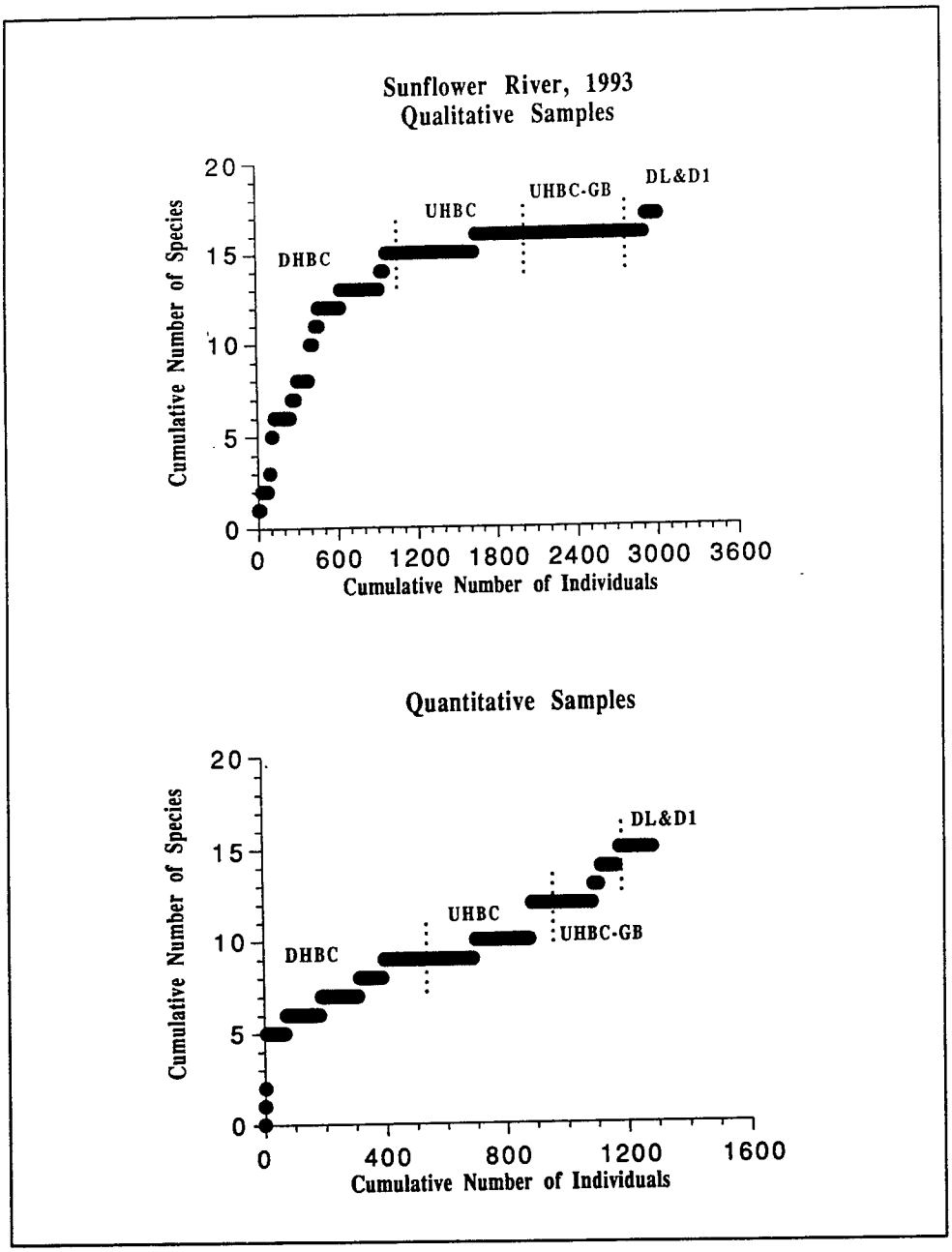


Figure 9. Relationship between cumulative number of species and cumulative number of individuals collected using qualitative and quantitative methods at four locations in Big Sunflower River (DHBC - downriver of Holly Bluff Cutoff; UHBC - upriver of Holly Bluff Cutoff; UHBC-GB - gravel bar upriver of Holly Bluff Cutoff; DL&D1 - downriver of Lock and Dam 1)

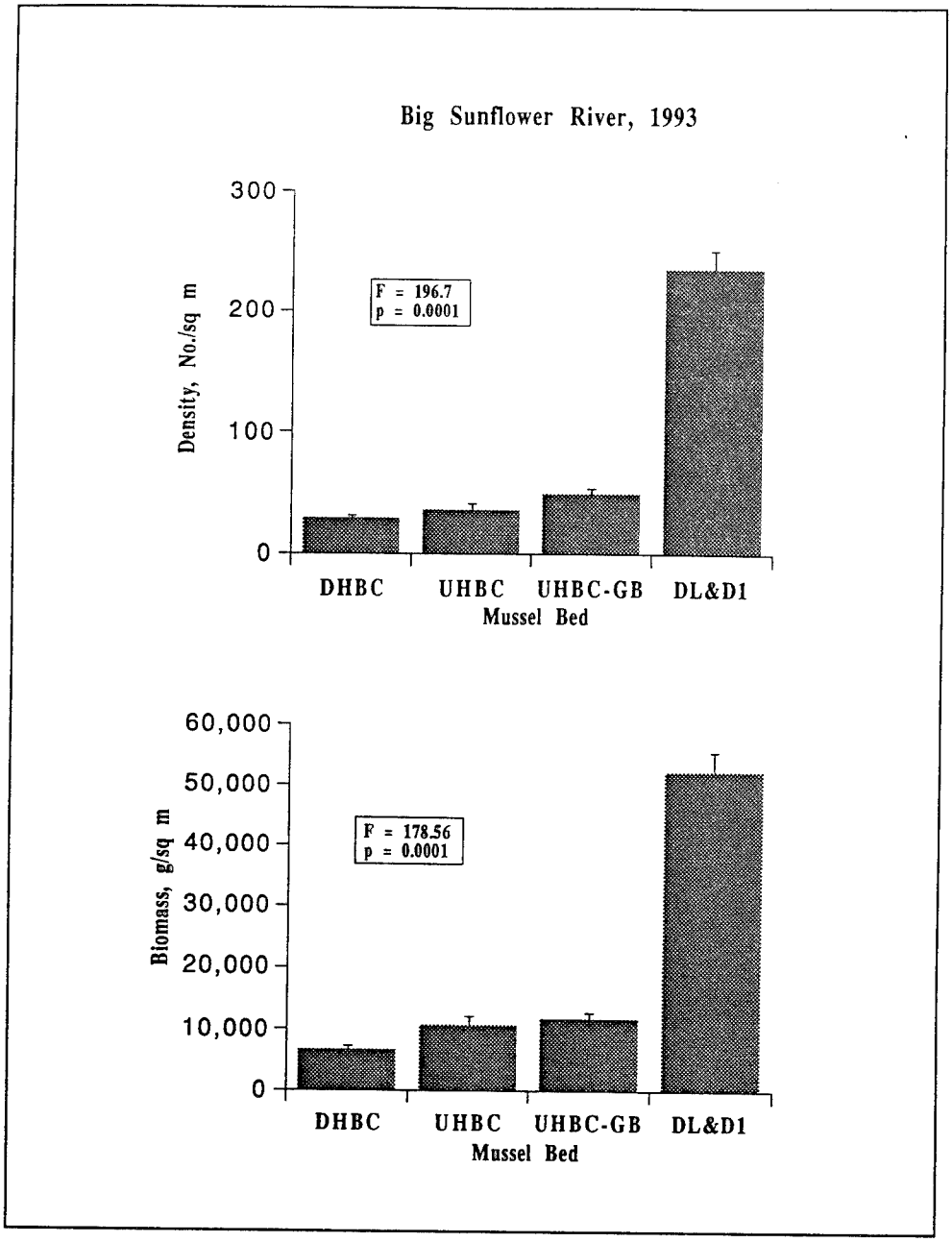


Figure 10. Mean density (individuals/sq m) and biomass (g/sq m) for freshwater mussels collected at four locations in Big Sunflower River. (DHBC - downriver of Holly Bluff Cutoff; UHBC - upriver of Holly Bluff Cutoff; UHBC-GB - gravel bar upriver of Holly Bluff Cutoff; DL&D1 - downriver of Lock and Dam 1)

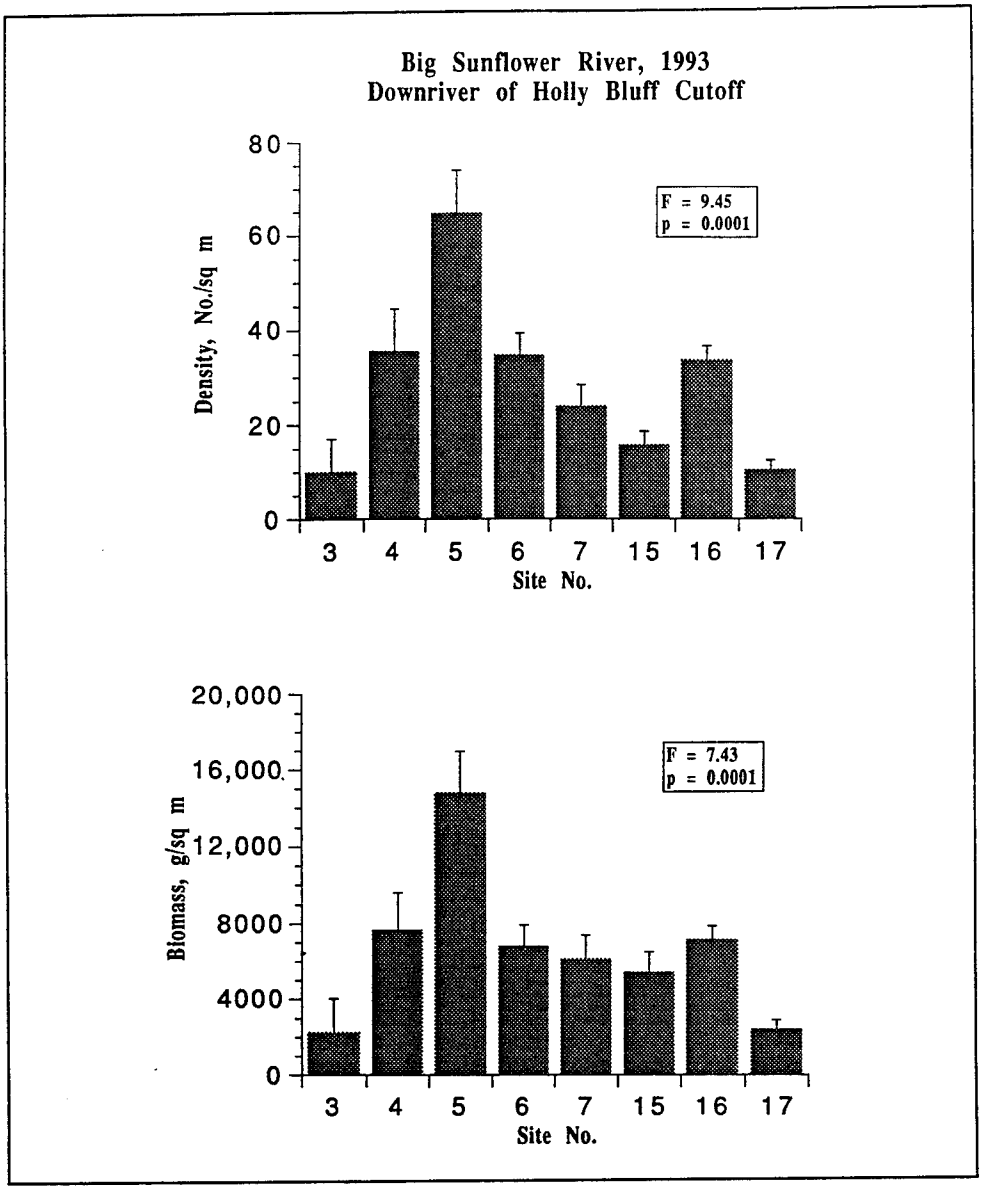


Figure 11. Mean density and biomass of mussels collected at eight sites on a bed located immediately downriver of Holly Bluff Cutoff. At each site, 10 quantitative (0.25 sq m) samples were collected by divers

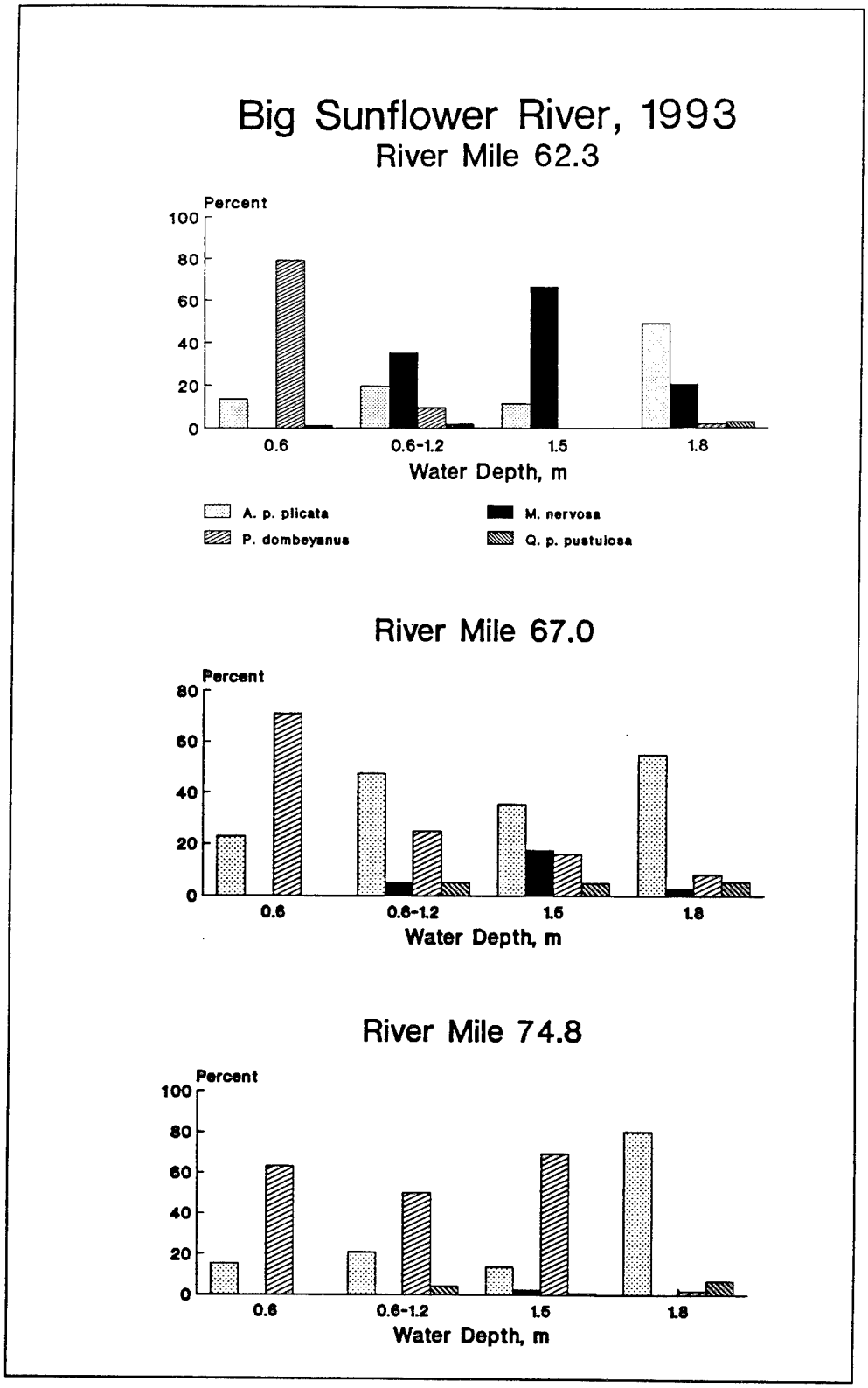


Figure 12. Distribution with respect to depth of dominant species of freshwater mussels collected at three locations upriver of Lock and Dam 1, Big Sunflower River

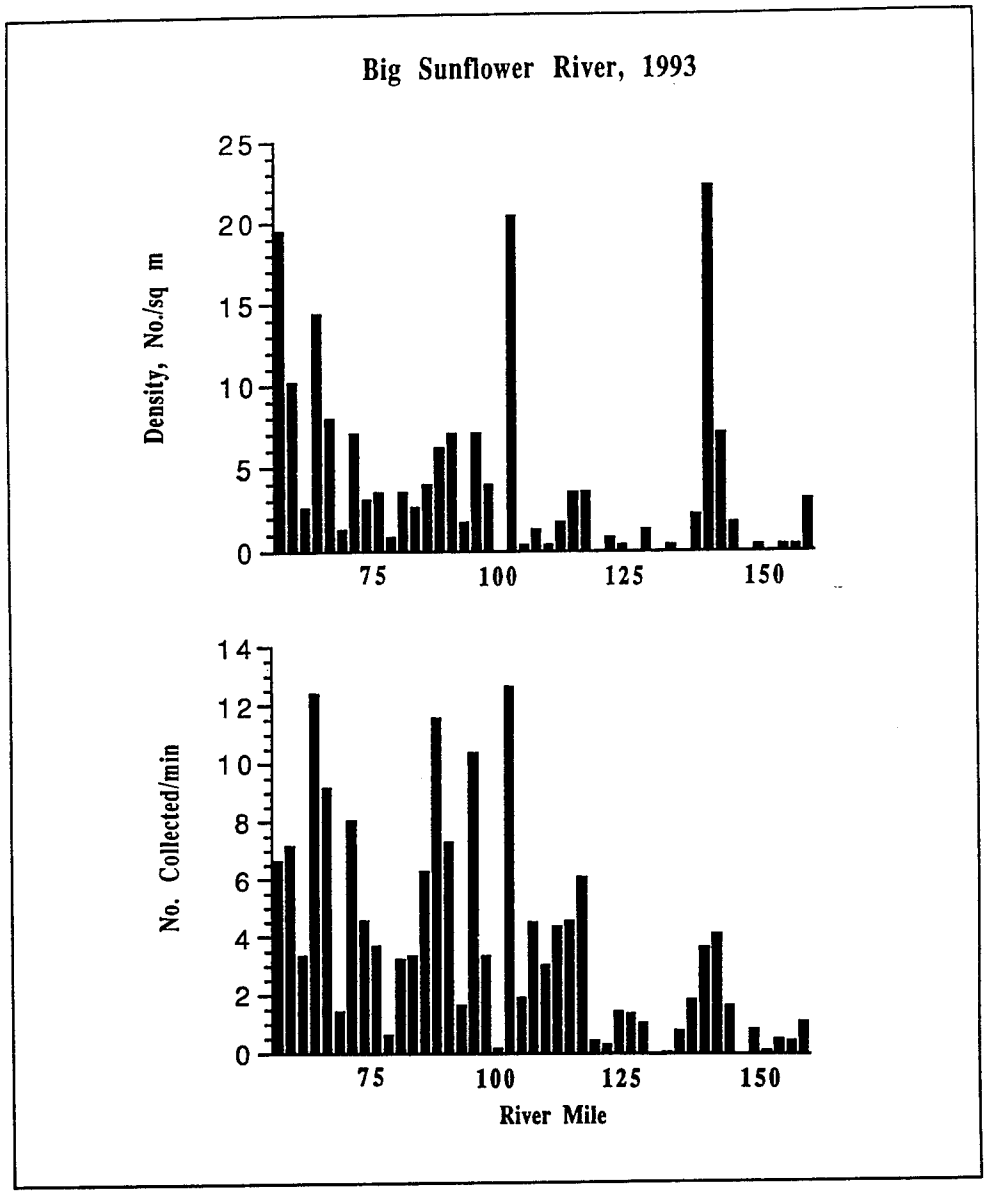


Figure 13. Density (individuals/sq m) and collection rate (individuals collected per min) at a series of shallow-water sites located between RM 62.2 and RM 149.2, Big Sunflower River

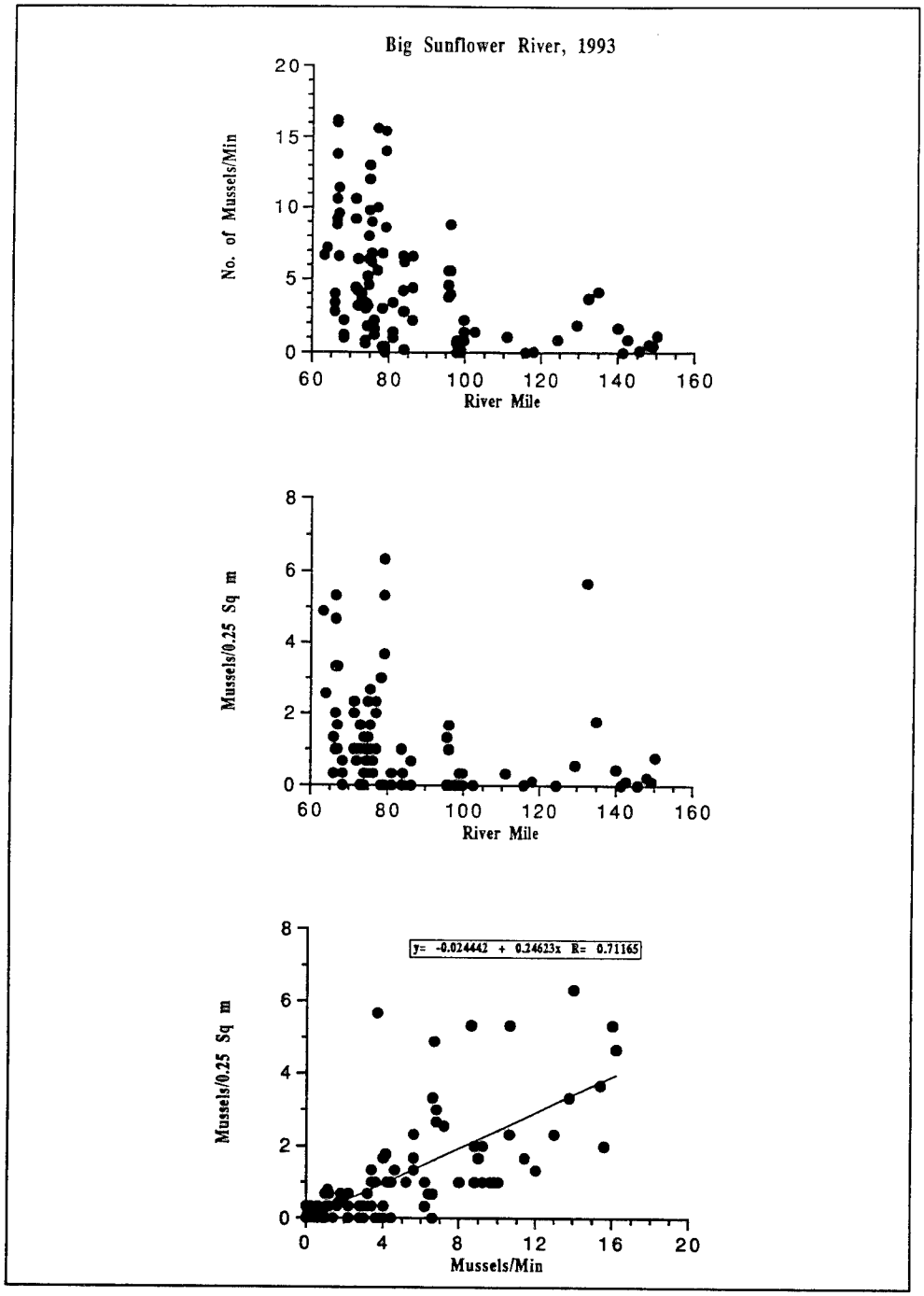


Figure 14. Relationships between river mile and collection rate and density and collecting rate for a series of shallow-water sites located between RM 62.2 and RM 149.2, Big Sunflower River

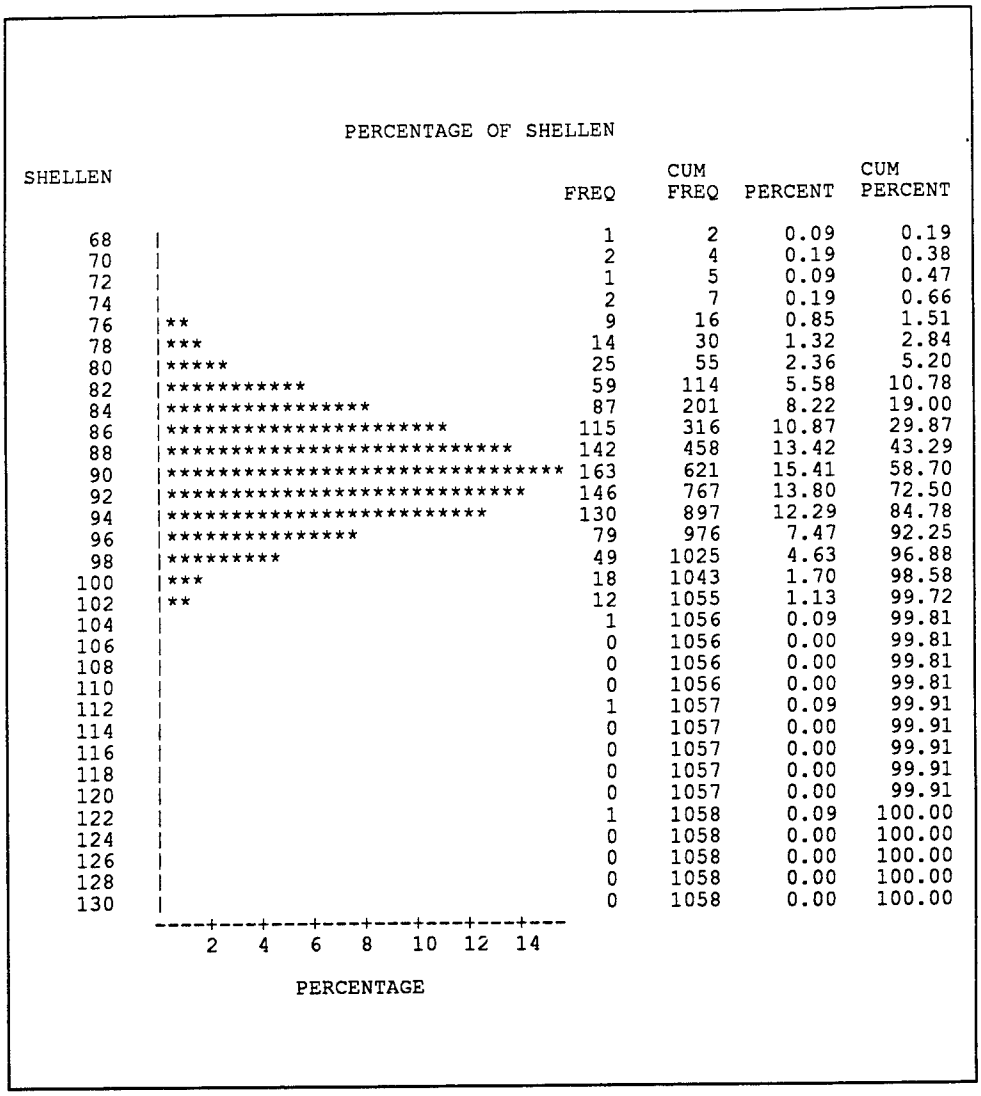


Figure 15. Length-frequency histogram for *Amblema plicata plicata* collected immediately downriver of Lock and Dam No. 1, Big Sunflower River, 1993

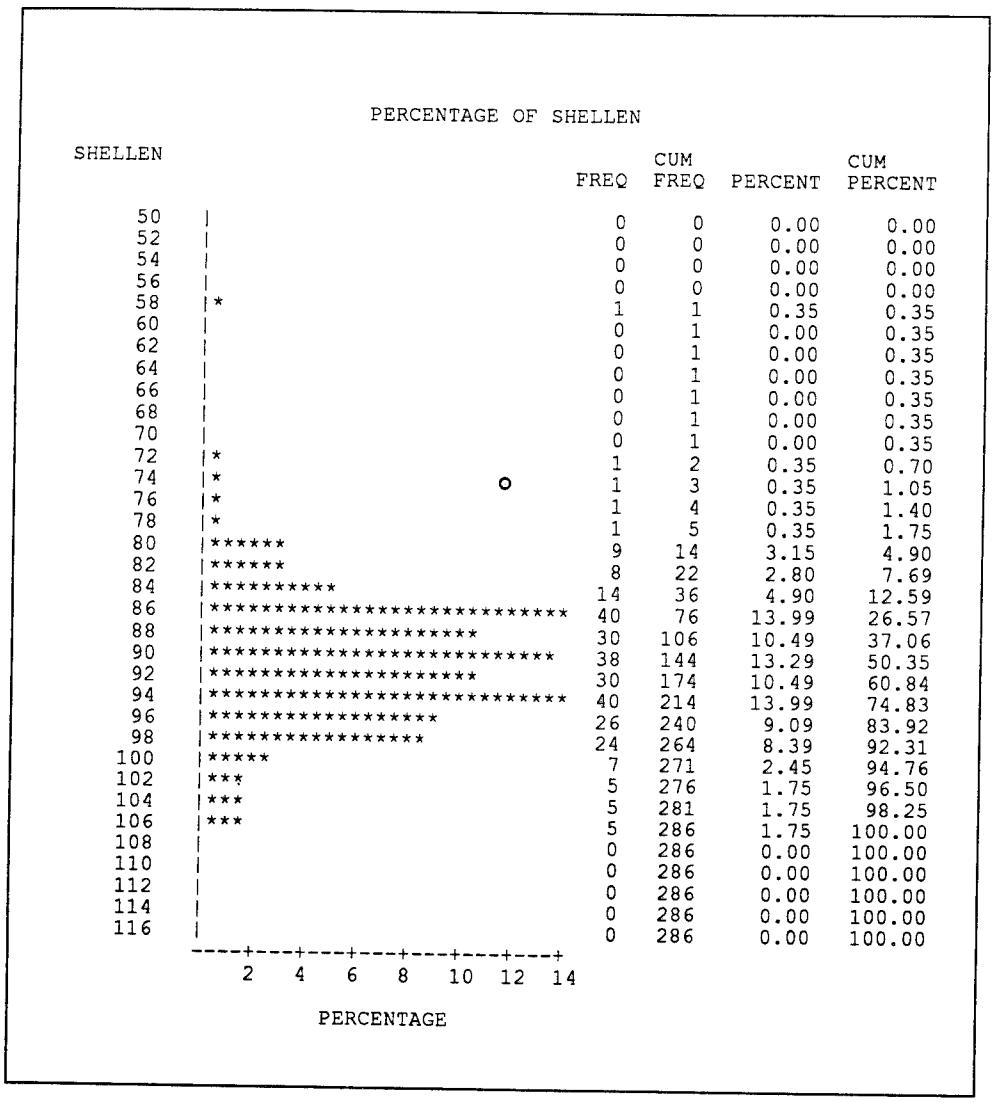
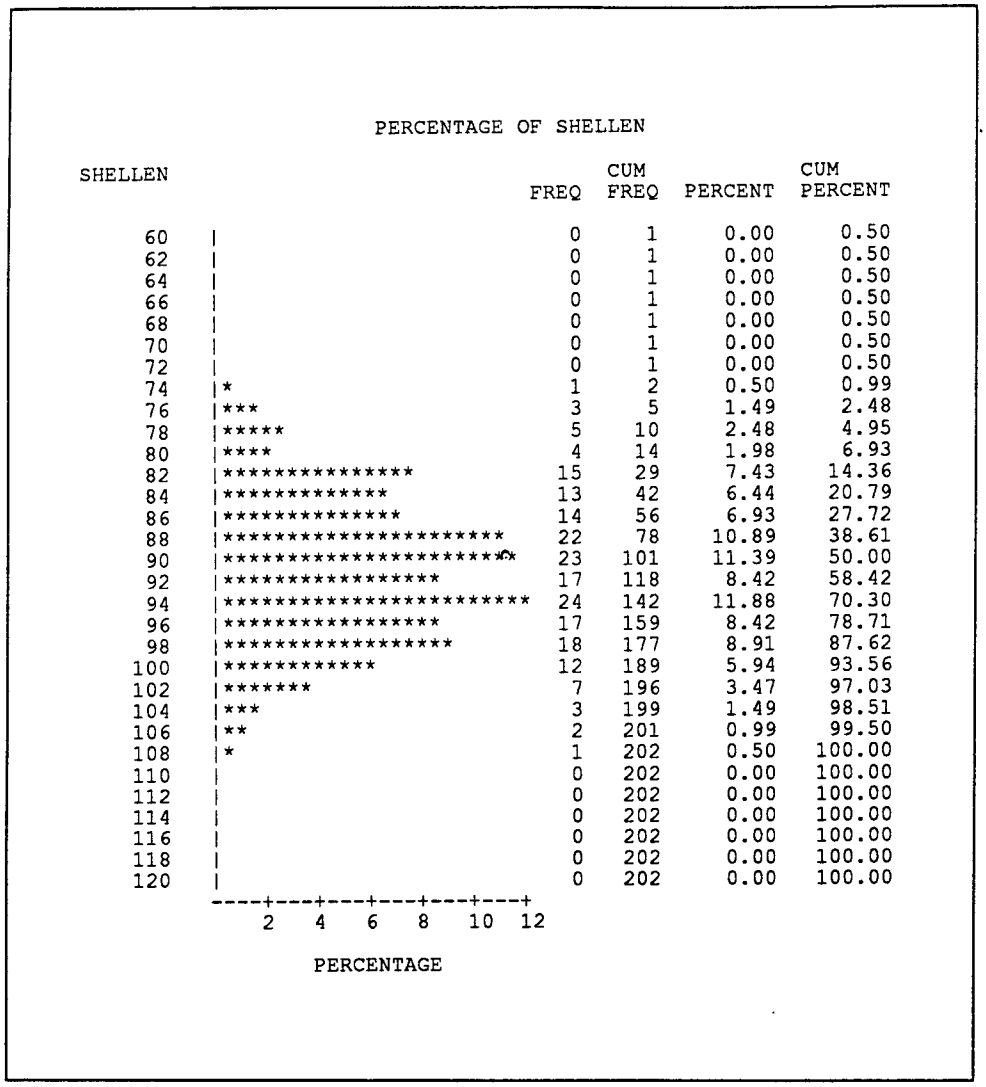


Figure 16. Length-frequency histogram for *Amblema plicata plicata* collected at a gravel bar upriver of Holly Bluff Cutoff, Big Sunflower River, 1993



PERCENTAGE OF SHELLEN

SHELLEN		FREQ	CUM FREQ	PERCENT	CUM PERCENT
60	|	0	1	0.00	0.50
62	|	0	1	0.00	0.50
64	|	0	1	0.00	0.50
66	|	0	1	0.00	0.50
68	|	0	1	0.00	0.50
70	|	0	1	0.00	0.50
72	|	0	1	0.00	0.50
74	|*	1	2	0.50	0.99
76	|***	3	5	1.49	2.48
78	|*****	5	10	2.48	4.95
80	|****	4	14	1.98	6.93
82	|***************	15	29	7.43	14.36
84	|*************	13	42	6.44	20.79
86	|**************	14	56	6.93	27.72
88	|**********************	22	78	10.89	38.61
90	|***********************	23	101	11.39	50.00
92	|*****************	17	118	8.42	58.42
94	|************************	24	142	11.88	70.30
96	|*****************	17	159	8.42	78.71
98	|******************	18	177	8.91	87.62
100	|************	12	189	5.94	93.56
102	|*******	7	196	3.47	97.03
104	|***	3	199	1.49	98.51
106	|**	2	201	0.99	99.50
108	|*	1	202	0.50	100.00
110	|	0	202	0.00	100.00
112	|	0	202	0.00	100.00
114	|	0	202	0.00	100.00
116	|	0	202	0.00	100.00
118	|	0	202	0.00	100.00
120	|	0	202	0.00	100.00

----+---+---+---+---+---+
2 4 6 8 10 12

PERCENTAGE

Figure 17. Length-frequency histogram for *Amblema plicata plicata* collected upriver of Holly Bluff Cutoff, Big Sunflower River, 1993

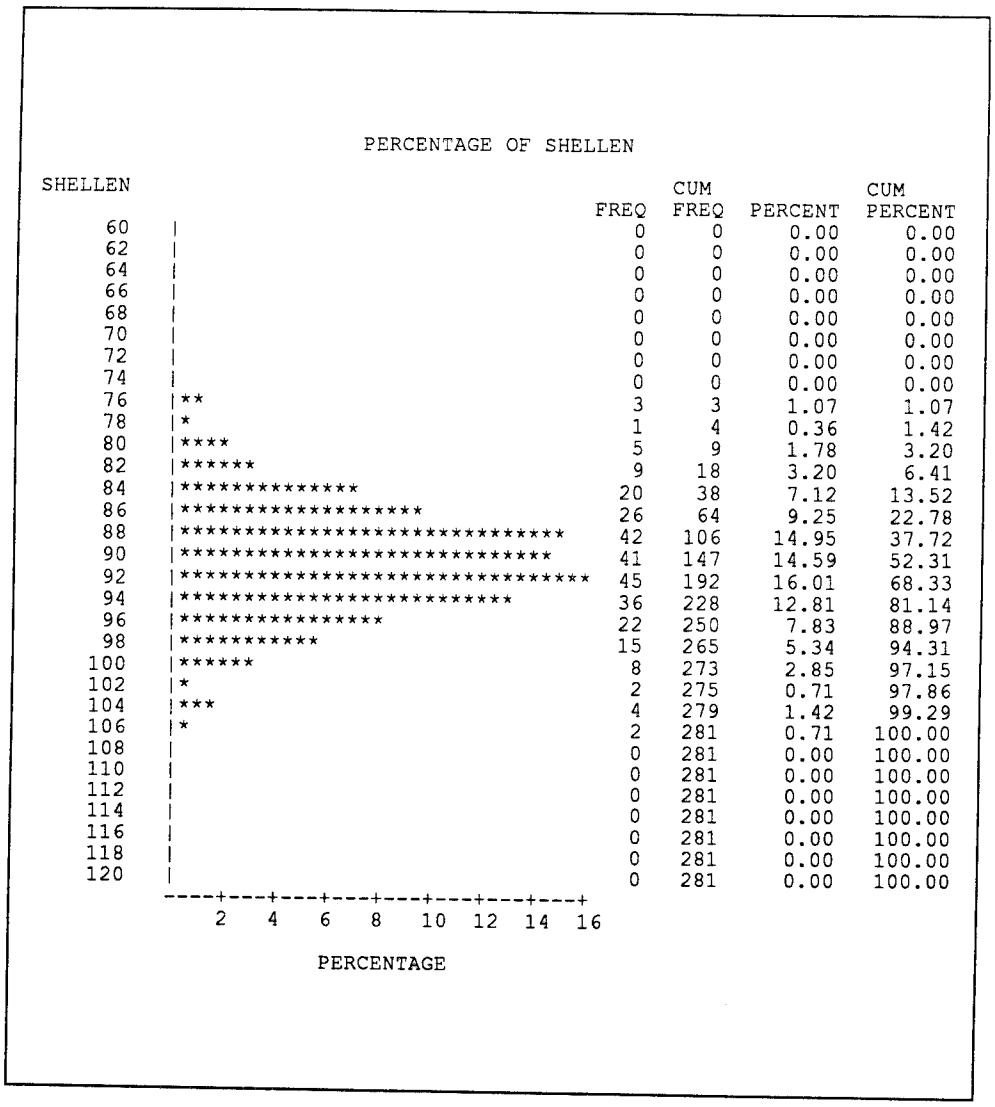


Figure 18. Length-frequency histogram for *Amblema plicata plicata* collected downriver of Holly Bluff Cutoff, Big Sunflower River, 1993

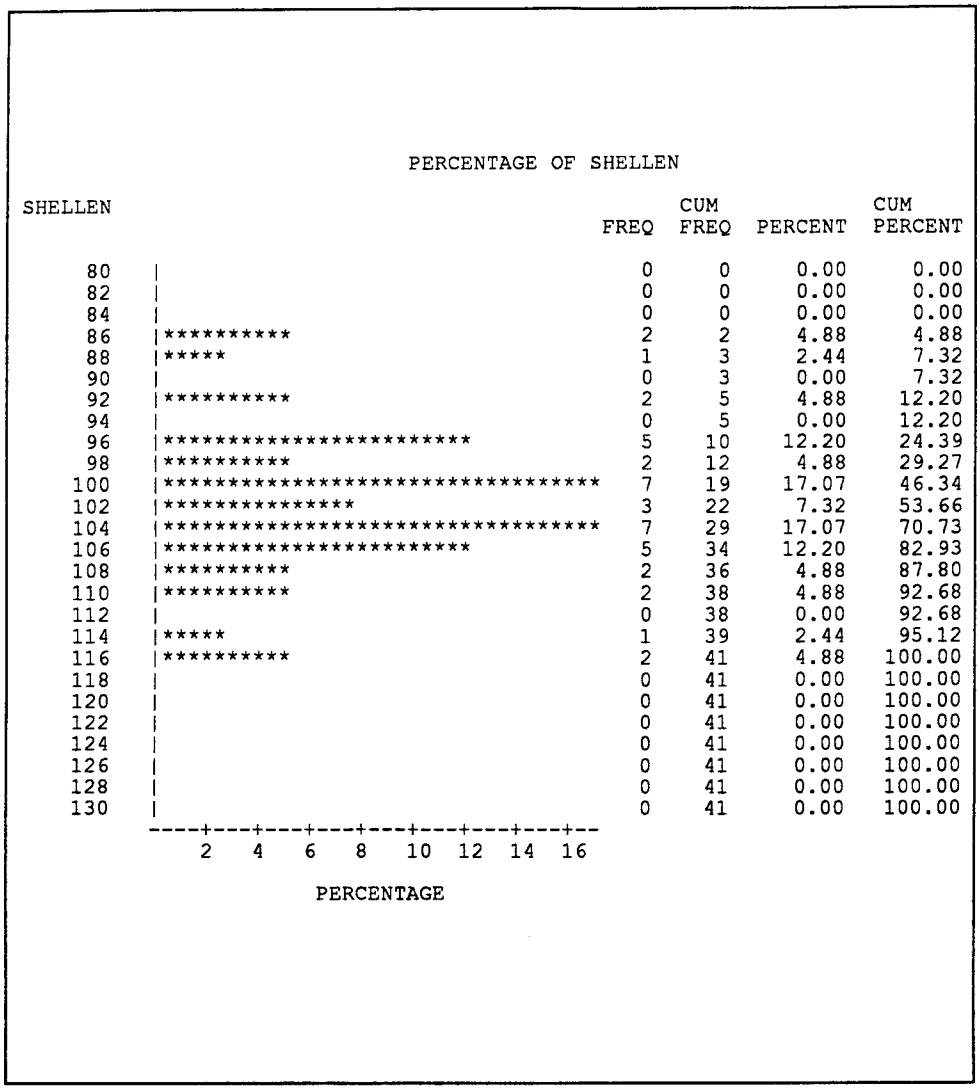


Figure 19. Length-frequency histogram for *Plectomerus dombeyanus* collected immediately downriver of Lock and Dam No. 1, Big Sunflower River, 1993

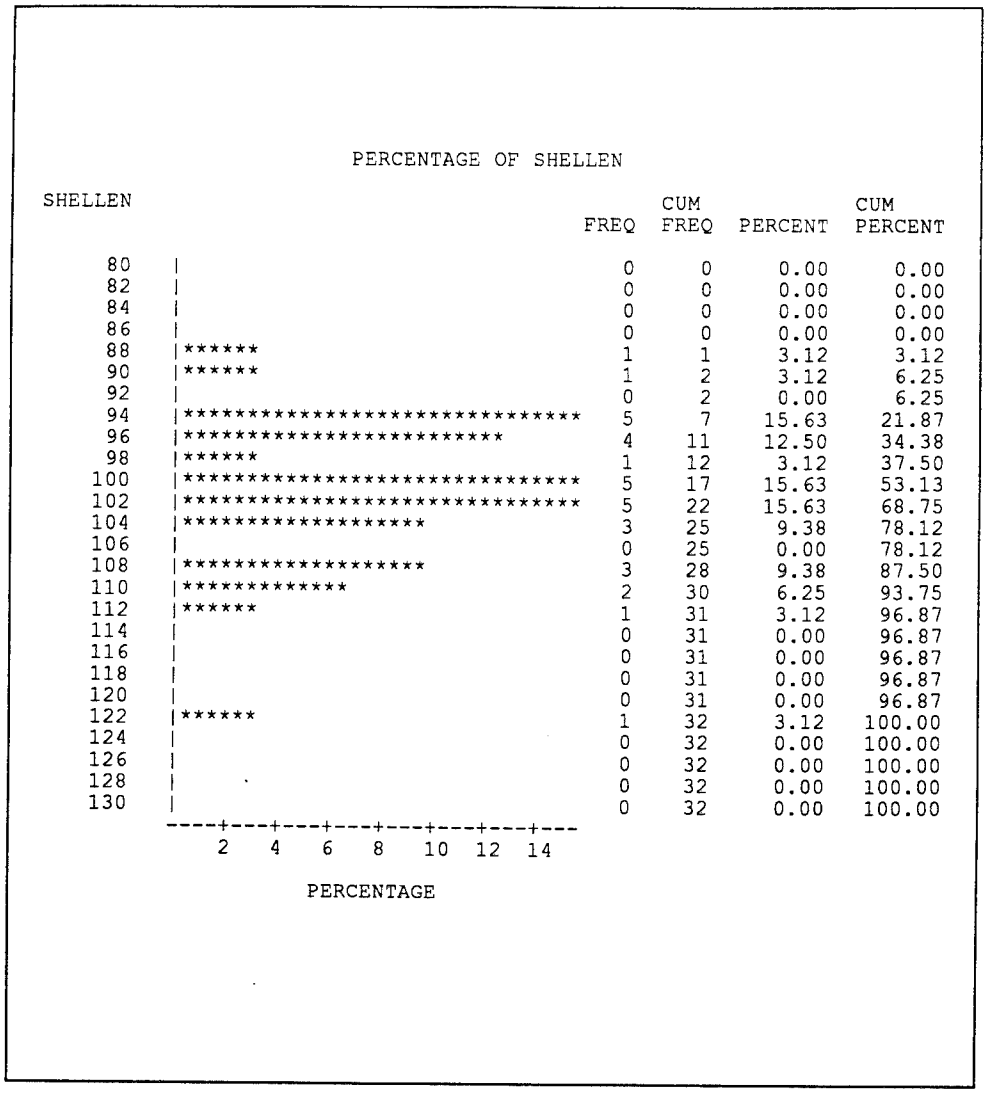


Figure 20. Length-frequency histogram for *Plectomerus dombeyanus* collected at a gravel bar upriver of Holly Bluff Cutoff, Big Sunflower River, 1993

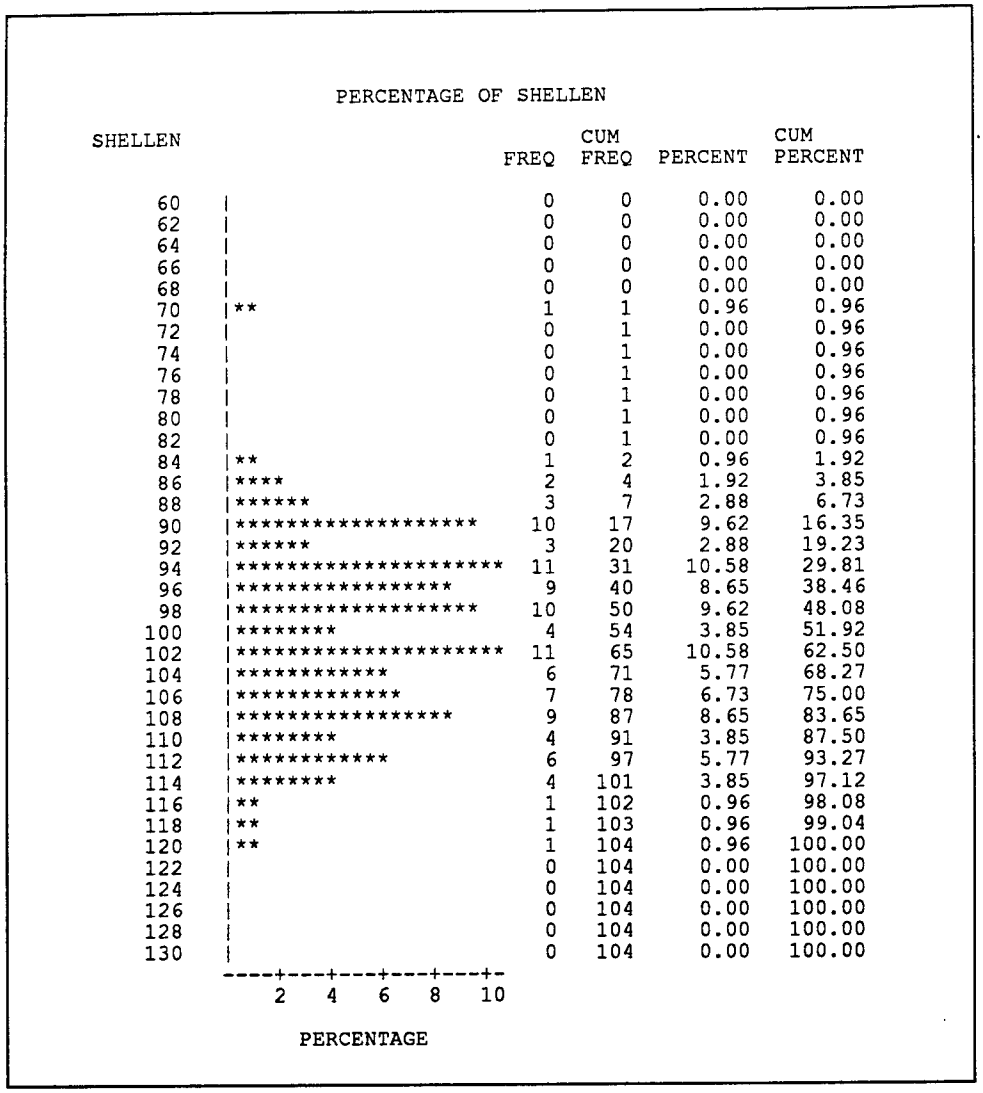


Figure 21. Length-frequency histogram for *Plectomerus dombeyanus* collected upriver of Holly Bluff Cutoff, Big Sunflower River, 1993

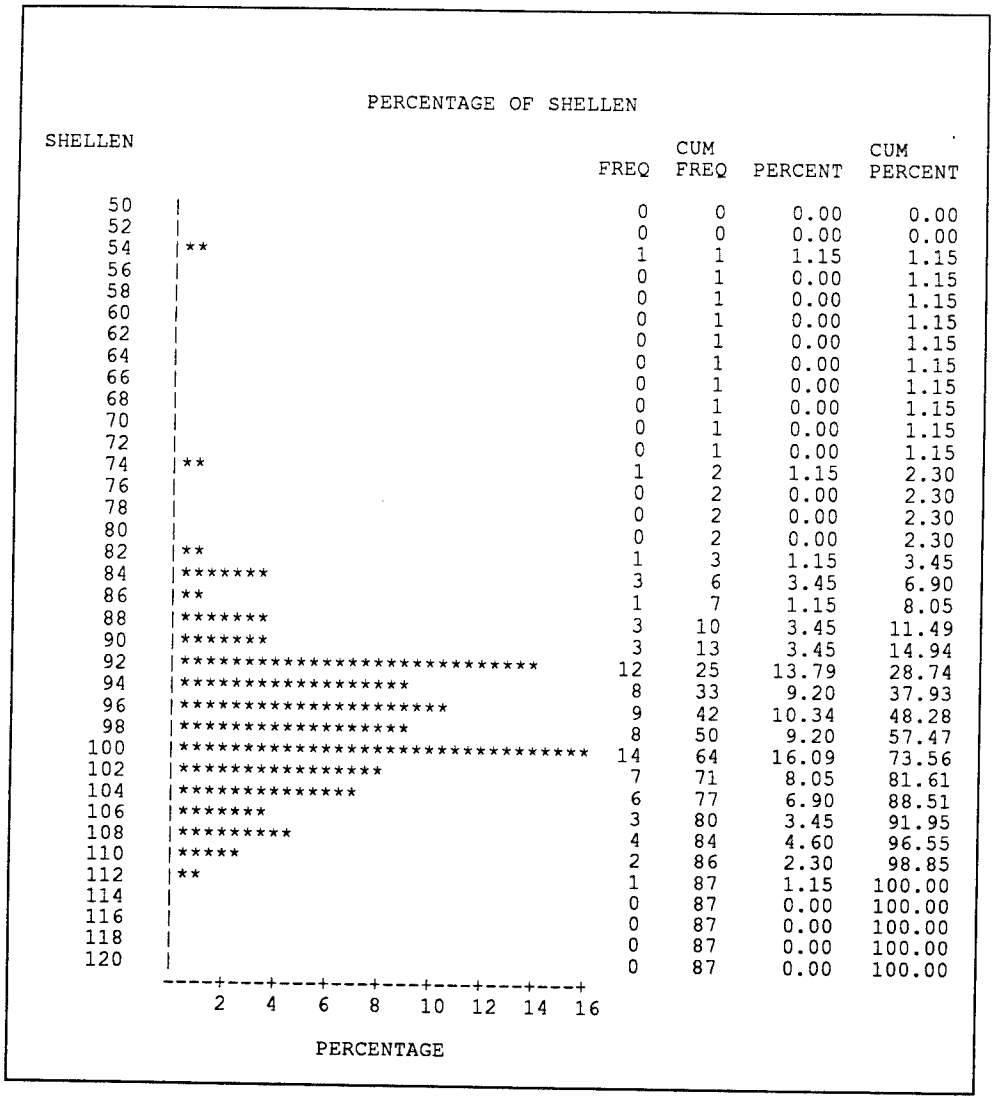


Figure 22. Length-frequency histogram for *Plectomerus dombeyanus* collected downriver of Holly Bluff Cutoff, Big Sunflower River, 1993

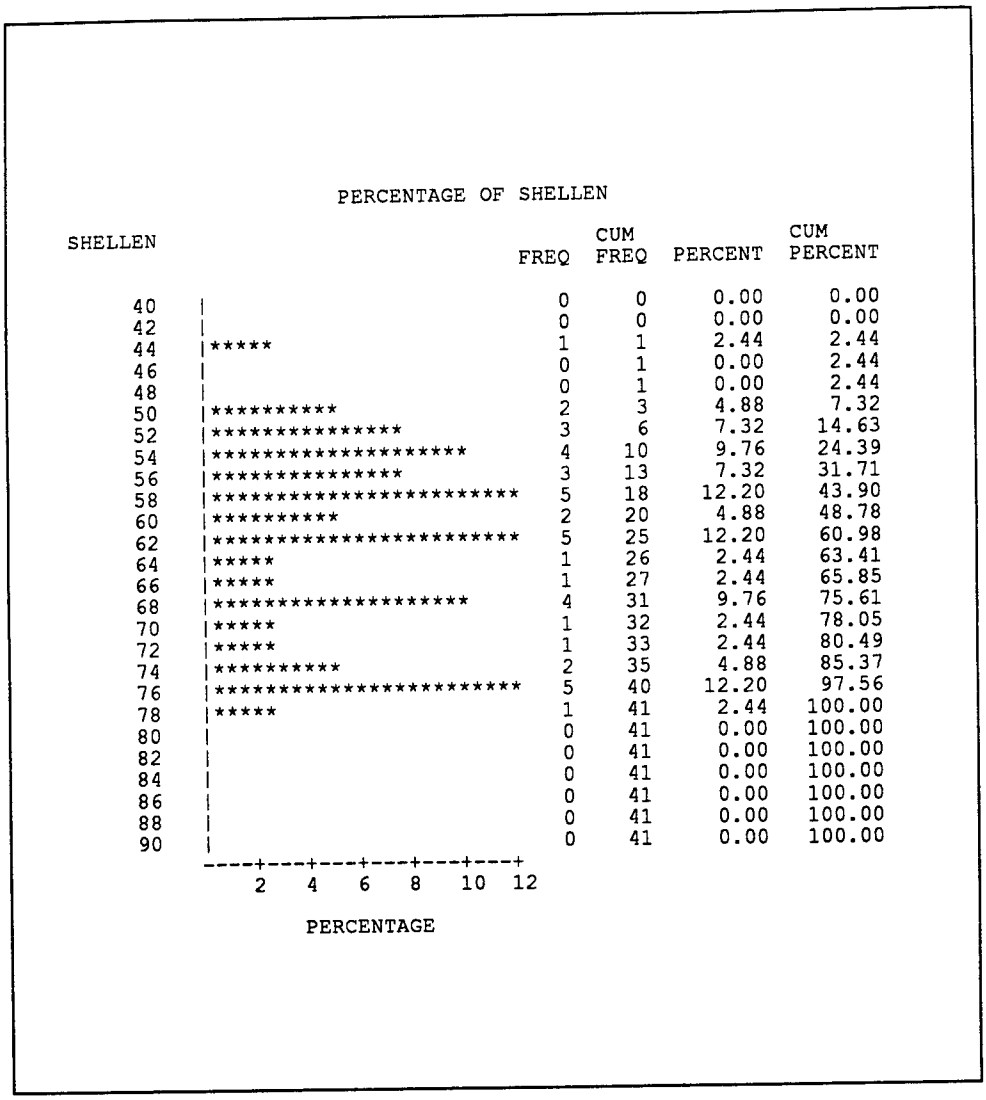


Figure 23. Length-frequency histogram for *Quadrula pustulosa pustulosa* collected immediately downriver of Lock and Dam No. 1, Big Sunflower River, 1993

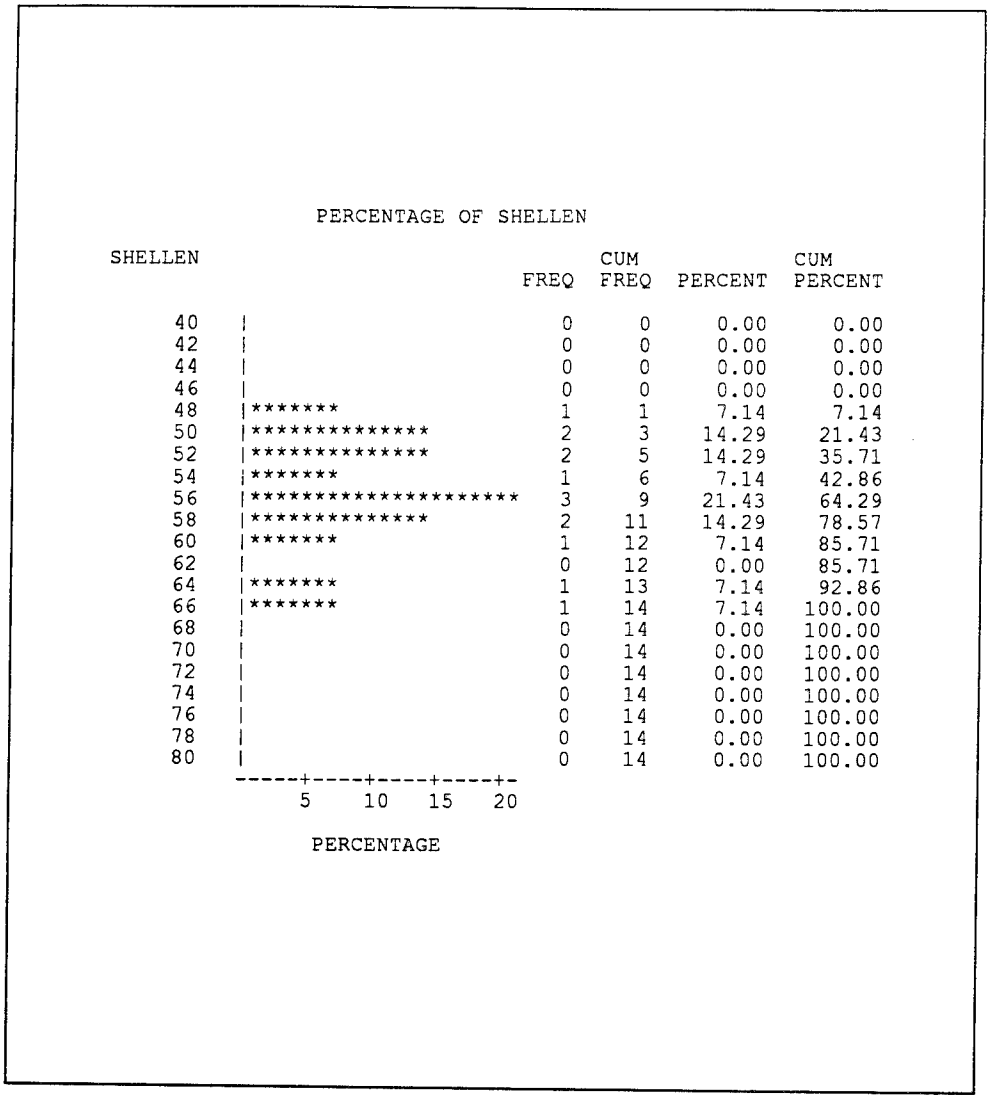


Figure 24. Length-frequency histogram for *Quadrula pustulosa pustulosa* collected at a gravel bar upriver of Holly Bluff Cutoff, Big Sunflower River, 1993

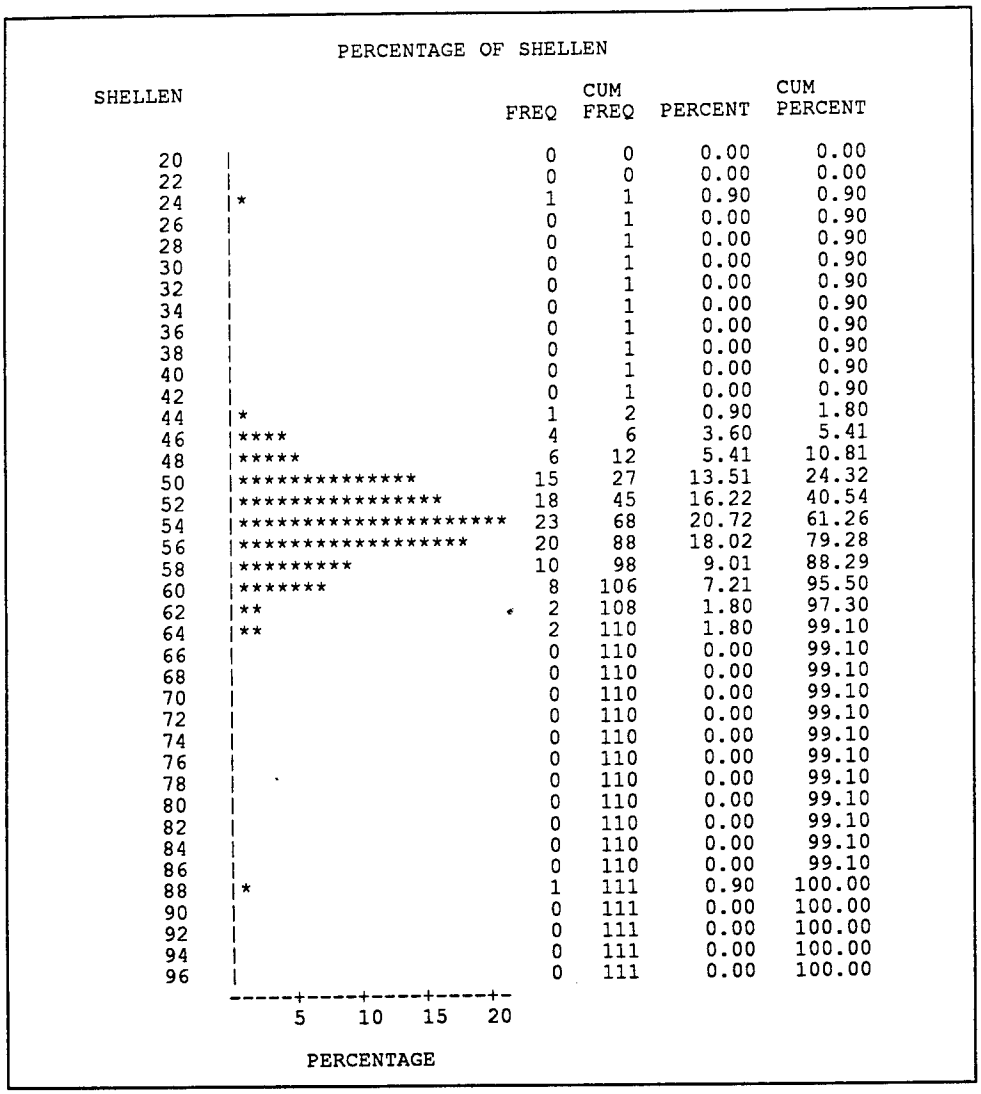


Figure 25. Length-frequency histogram for *Quadrula pustulosa pustulosa* collected downriver of Holly Bluff Cutoff, Big Sunflower River, 1993

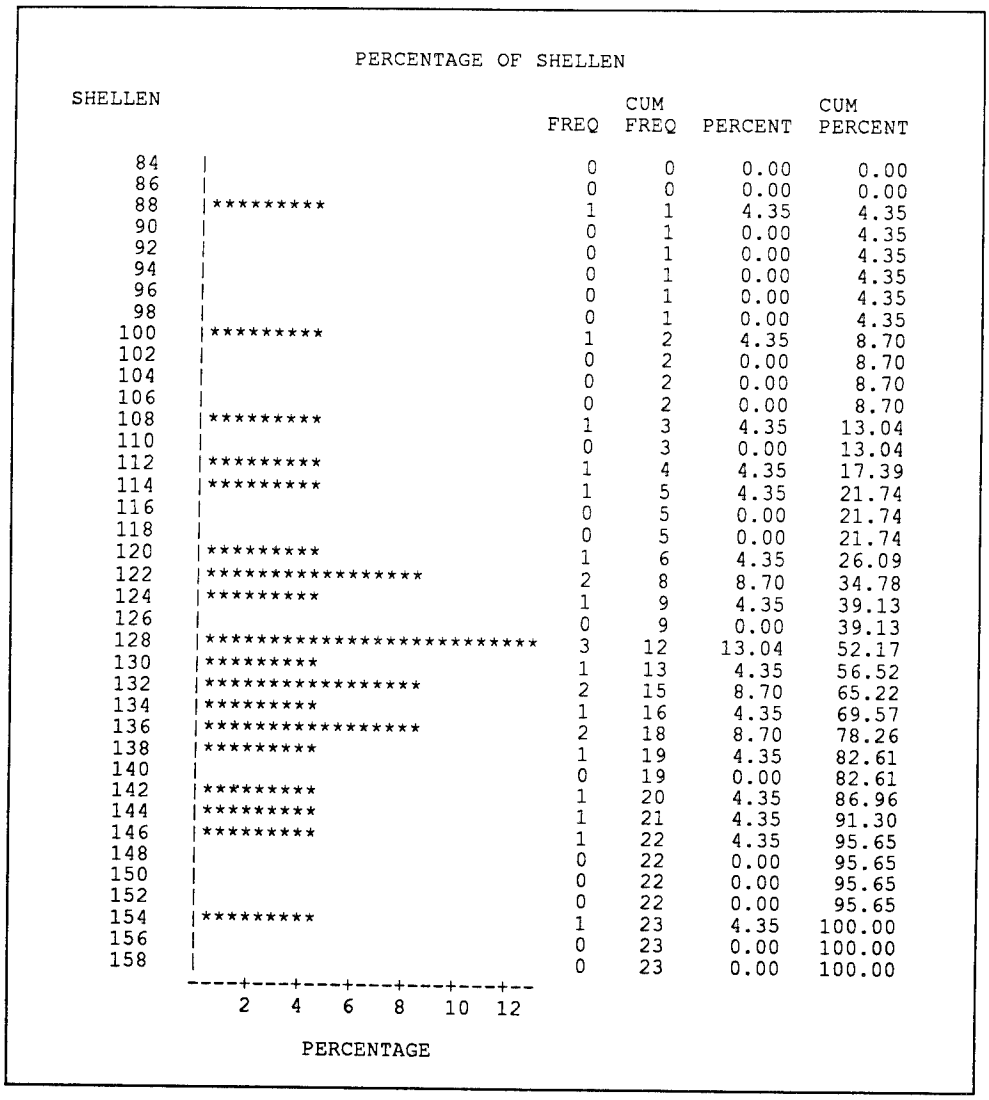


Figure 26. Length-frequency histogram for *Megalonaias nervosa* collected upriver of Holly Bluff Cutoff, Big Sunflower River, 1993

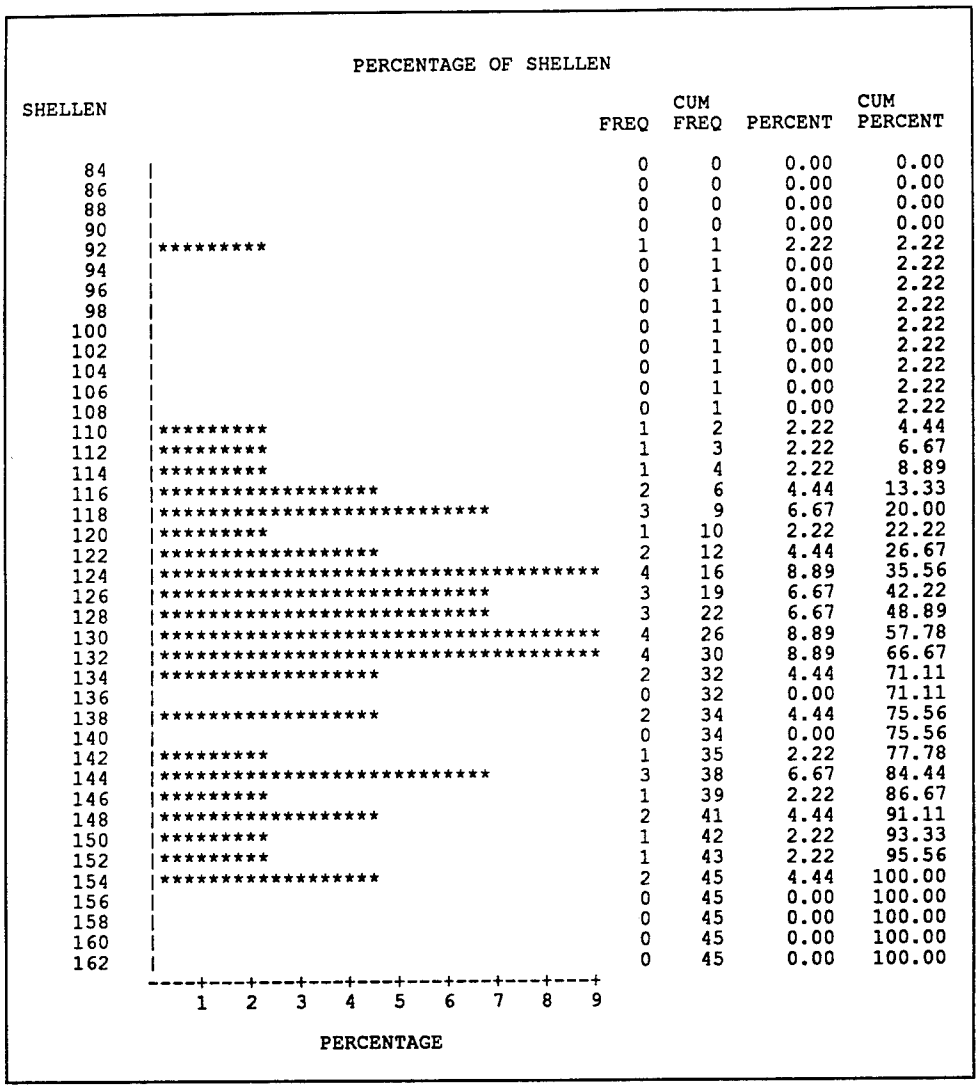
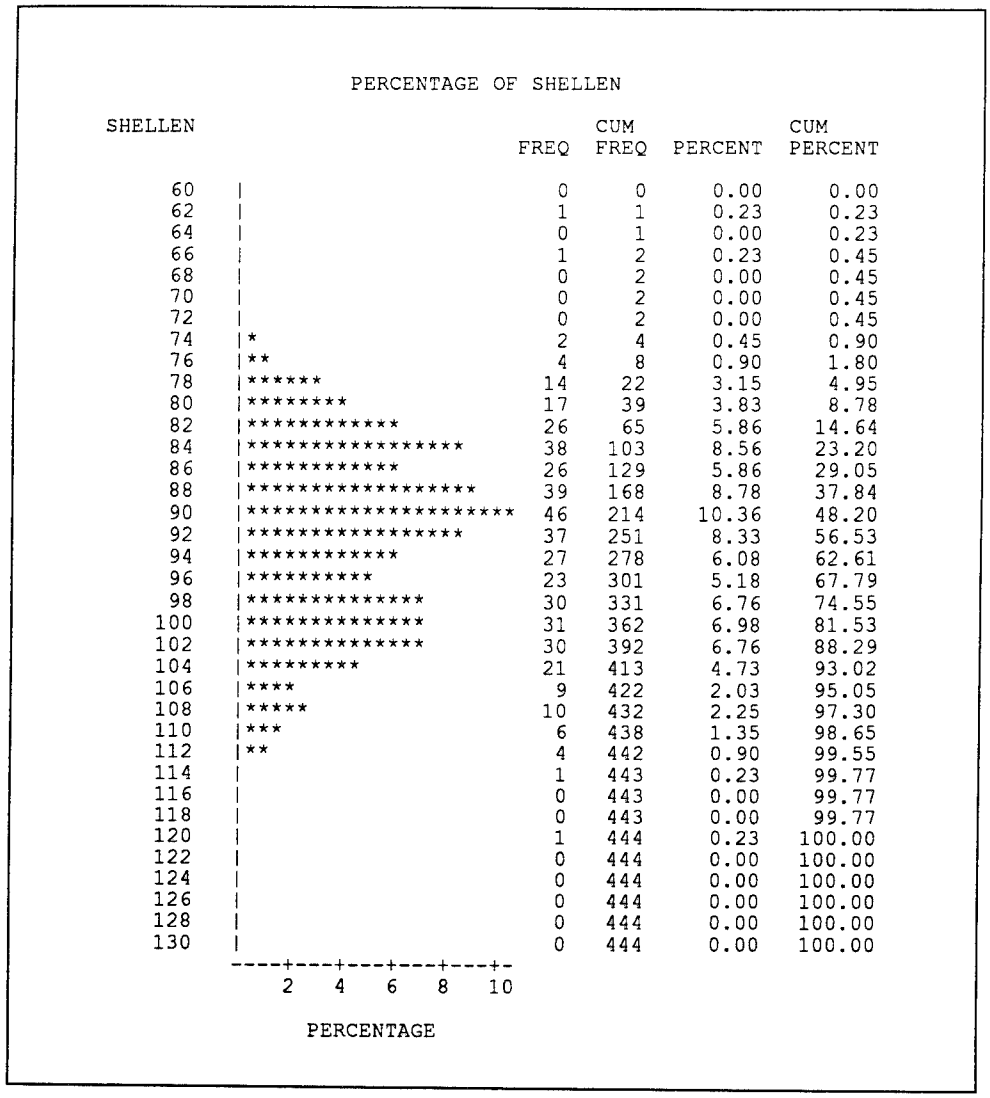


Figure 27. Length-frequency histogram for *Megalonaias nervosa* collected downriver of Holly Bluff Cutoff, Big Sunflower River, 1993



PERCENTAGE OF SHELLEN

SHELLEN		FREQ	CUM FREQ	PERCENT	CUM PERCENT
60	|	0	0	0.00	0.00
62	|	1	1	0.23	0.23
64	|	0	1	0.00	0.23
66	|	1	2	0.23	0.45
68	|	0	2	0.00	0.45
70	|	0	2	0.00	0.45
72	|	0	2	0.00	0.45
74	|*	2	4	0.45	0.90
76	|**	4	8	0.90	1.80
78	|******	14	22	3.15	4.95
80	|********	17	39	3.83	8.78
82	|************	26	65	5.86	14.64
84	|*****************	38	103	8.56	23.20
86	|************	26	129	5.86	29.05
88	|******************	39	168	8.78	37.84
90	|**********************	46	214	10.36	48.20
92	|*****************	37	251	8.33	56.53
94	|************	27	278	6.08	62.61
96	|**********	23	301	5.18	67.79
98	|**************	30	331	6.76	74.55
100	|**************	31	362	6.98	81.53
102	|**************	30	392	6.76	88.29
104	|*********	21	413	4.73	93.02
106	|****	9	422	2.03	95.05
108	|*****	10	432	2.25	97.30
110	|***	6	438	1.35	98.65
112	|**	4	442	0.90	99.55
114	|	1	443	0.23	99.77
116	|	0	443	0.00	99.77
118	|	0	443	0.00	99.77
120	|	1	444	0.23	100.00
122	|	0	444	0.00	100.00
124	|	0	444	0.00	100.00
126	|	0	444	0.00	100.00
128	|	0	444	0.00	100.00
130	|	0	444	0.00	100.00

----+---+---+---+---+-
2 4 6 8 10

PERCENTAGE

Figure 28. Length-frequency histogram for *Amblema plicata plicata* collected at a gravel bar upriver of Holly Bluff Cutoff, Big Sunflower River, 1987 (from Miller, Payne, and Hartfield 1992)

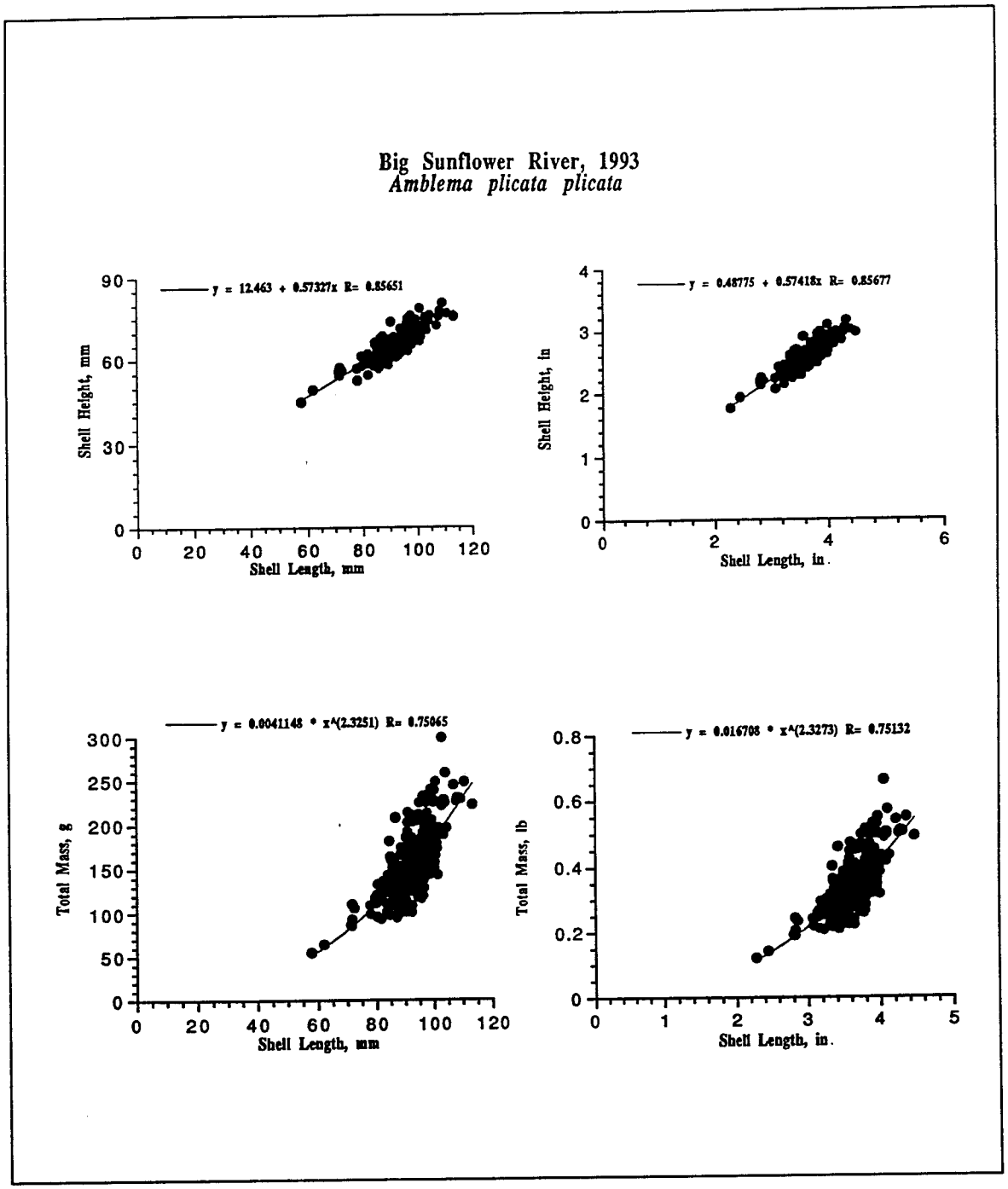


Figure 29. Relationships between shell length and shell height and total mass, in metric and English units, for *Amblema plicata plicata*, Big Sunflower River

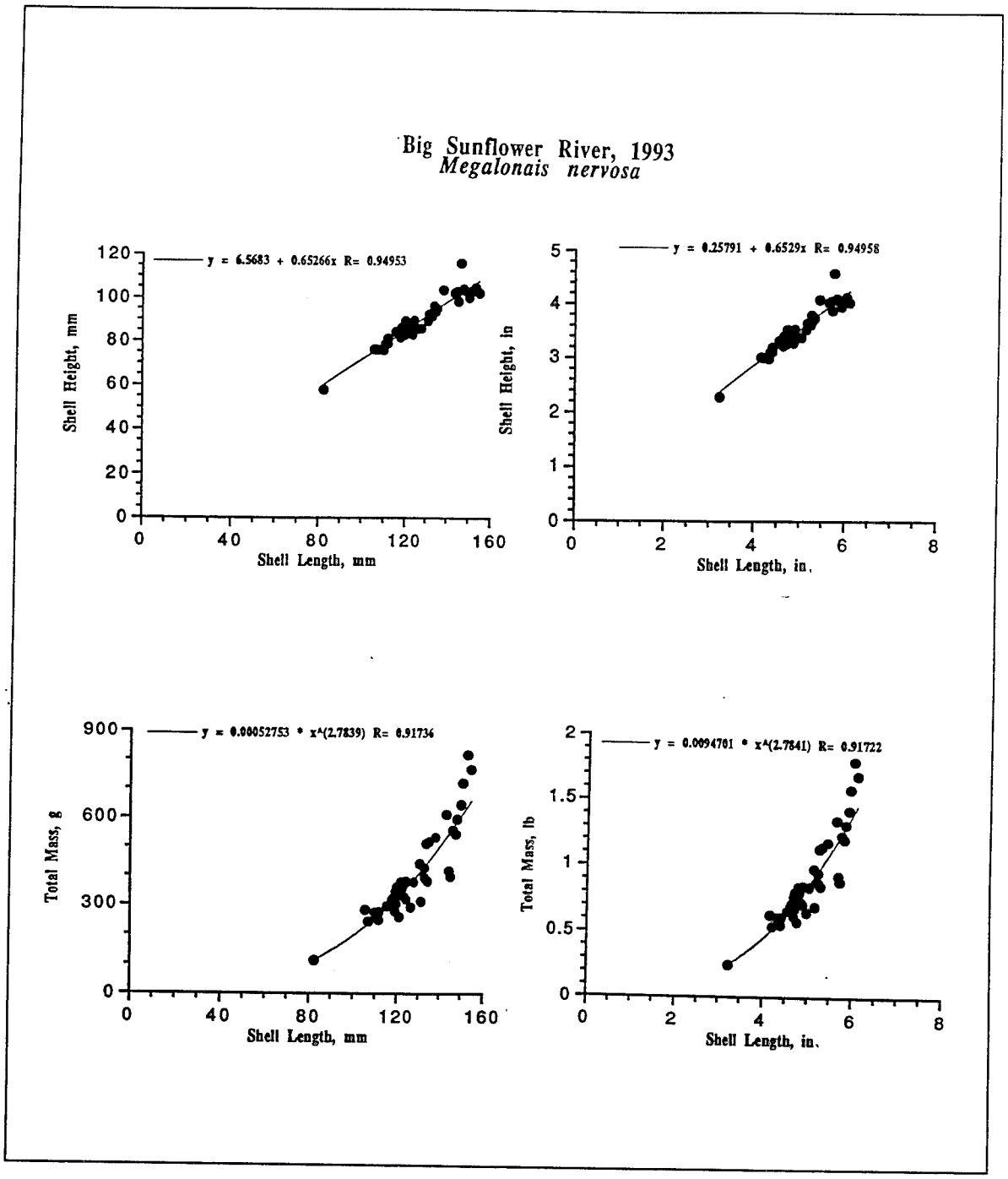


Figure 30. Relationships between shell length and shell height and total mass, in metric and English units, for *Megalonaias nervosa*, Big Sunflower River

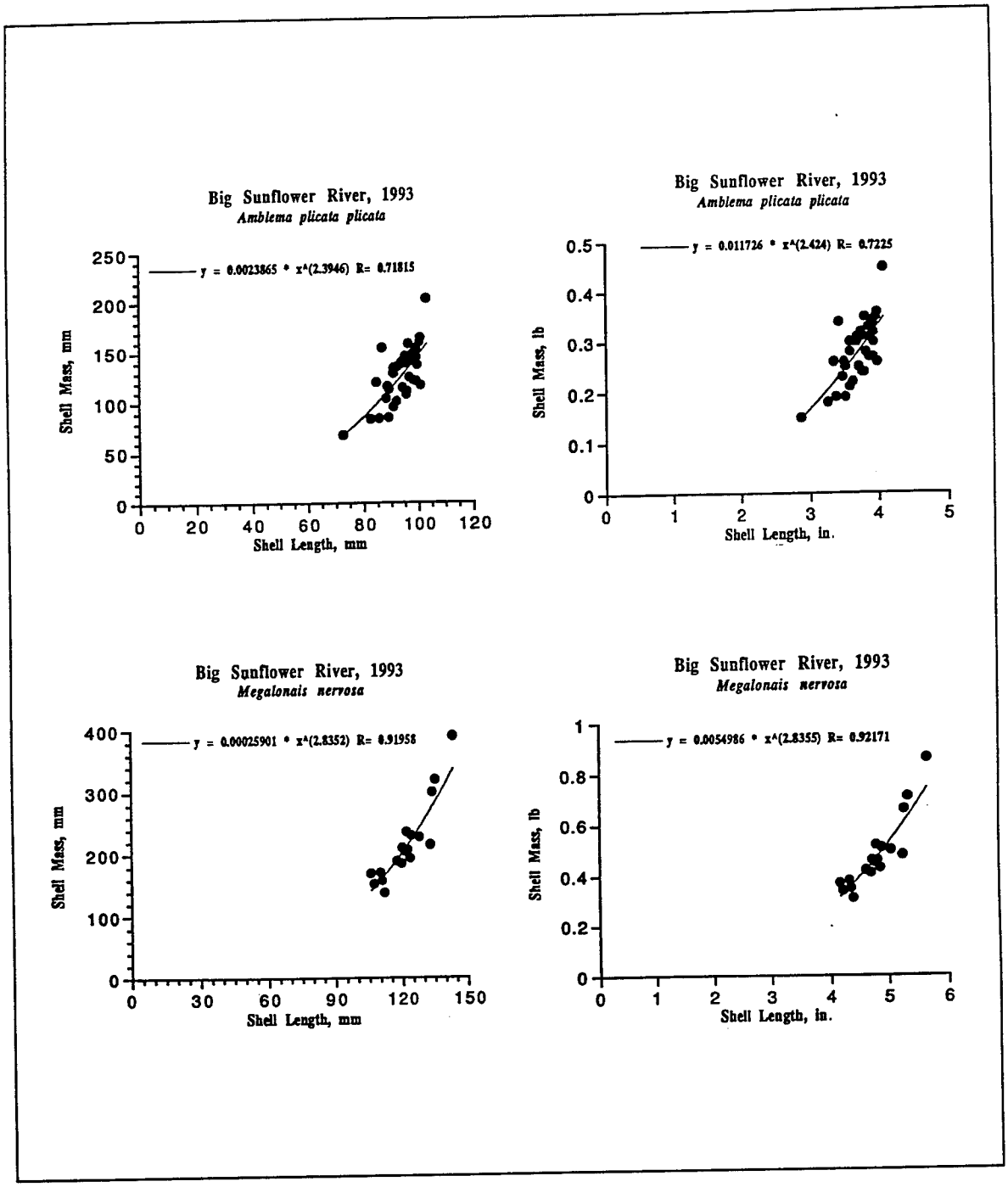
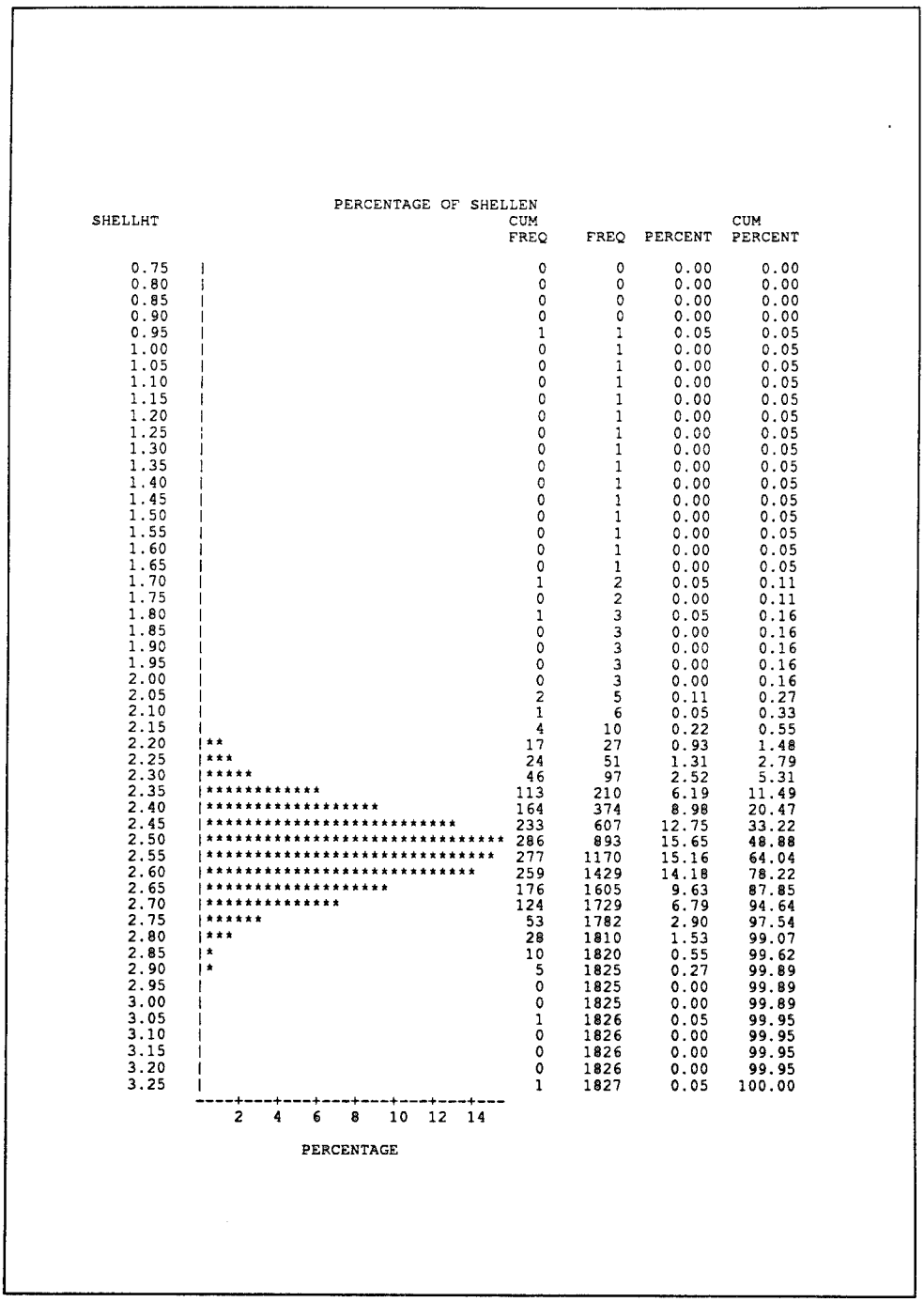


Figure 31. Relationships between shell length and shell mass, in metric and English units, for *Amblema plicata plicata* and *Megalonaias nervosa*, Big Sunflower River



SHELLHT		CUM FREQ	FREQ	PERCENT	CUM PERCENT
0.75		0	0	0.00	0.00
0.80		0	0	0.00	0.00
0.85		0	0	0.00	0.00
0.90		0	0	0.00	0.00
0.95		1	1	0.05	0.05
1.00		0	1	0.00	0.05
1.05		0	1	0.00	0.05
1.10		0	1	0.00	0.05
1.15		0	1	0.00	0.05
1.20		0	1	0.00	0.05
1.25		0	1	0.00	0.05
1.30		0	1	0.00	0.05
1.35		0	1	0.00	0.05
1.40		0	1	0.00	0.05
1.45		0	1	0.00	0.05
1.50		0	1	0.00	0.05
1.55		0	1	0.00	0.05
1.60		0	1	0.00	0.05
1.65		0	1	0.00	0.05
1.70		1	2	0.05	0.11
1.75		0	2	0.00	0.11
1.80		1	3	0.05	0.16
1.85		0	3	0.00	0.16
1.90		0	3	0.00	0.16
1.95		0	3	0.00	0.16
2.00		0	3	0.00	0.16
2.05		2	5	0.11	0.27
2.10		1	6	0.05	0.33
2.15		4	10	0.22	0.55
2.20	**	17	27	0.93	1.48
2.25	***	24	51	1.31	2.79
2.30	*****	46	97	2.52	5.31
2.35	**********	113	210	6.19	11.49
2.40	**********	164	374	8.98	20.47
2.45	**********	233	607	12.75	33.22
2.50	**********	286	893	15.65	48.88
2.55	**********	277	1170	15.16	64.04
2.60	**********	259	1429	14.18	78.22
2.65	**********	176	1605	9.63	87.85
2.70	**********	124	1729	6.79	94.64
2.75	******	53	1782	2.90	97.54
2.80	***	28	1810	1.53	99.07
2.85	*	10	1820	0.55	99.62
2.90	*	5	1825	0.27	99.89
2.95		0	1825	0.00	99.89
3.00		0	1825	0.00	99.89
3.05		1	1826	0.05	99.95
3.10		0	1826	0.00	99.95
3.15		0	1826	0.00	99.95
3.20		0	1826	0.00	99.95
3.25		1	1827	0.05	100.00

Figure 32. Length-frequency histogram based on shell heights (English units) for *Amblema plicata plicata*, all sites combined, September 1993

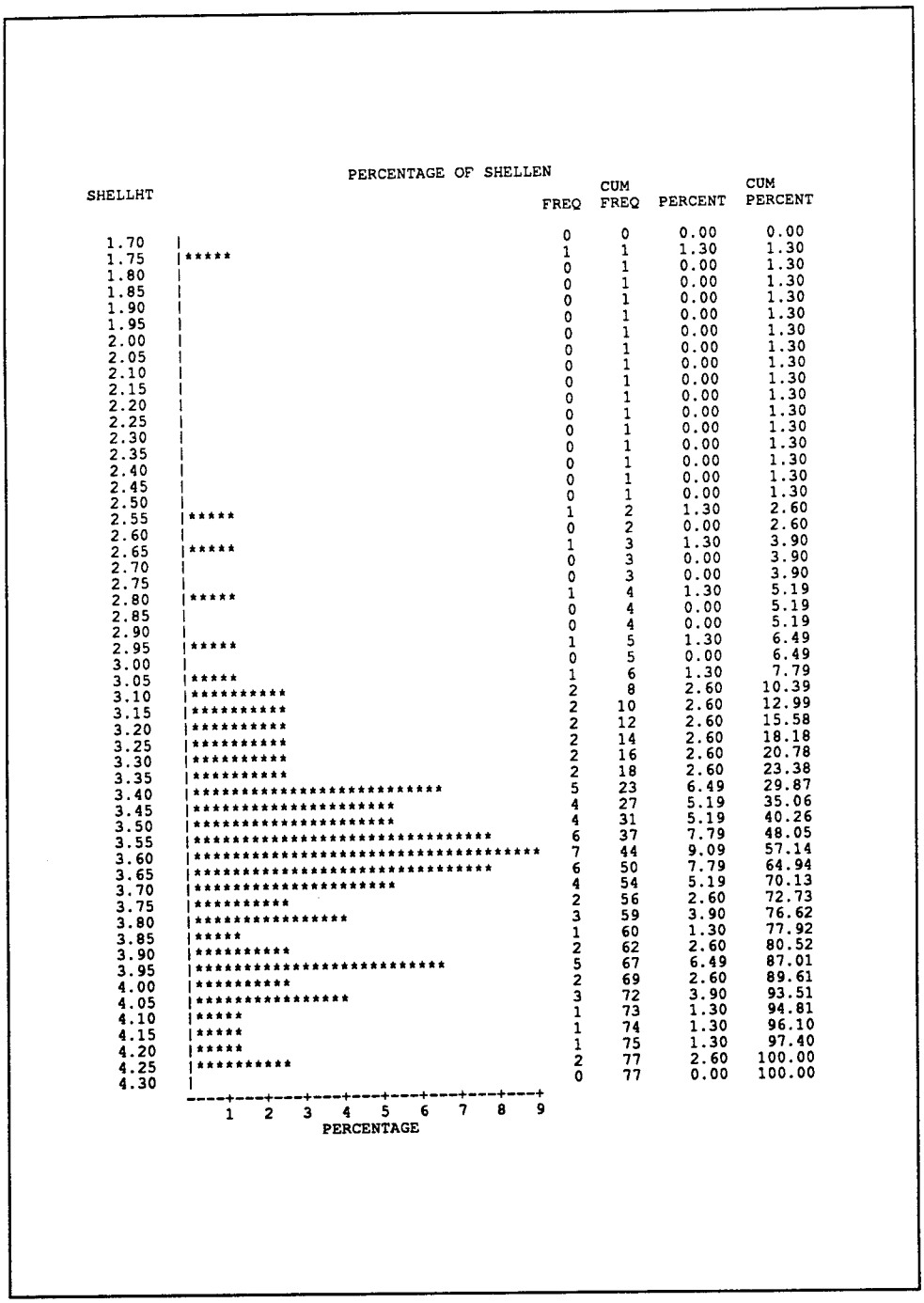


Figure 33. Length-frequency histogram based on shell heights (English units) for *Megalonaias nervosa*, all sites combined, September 1993

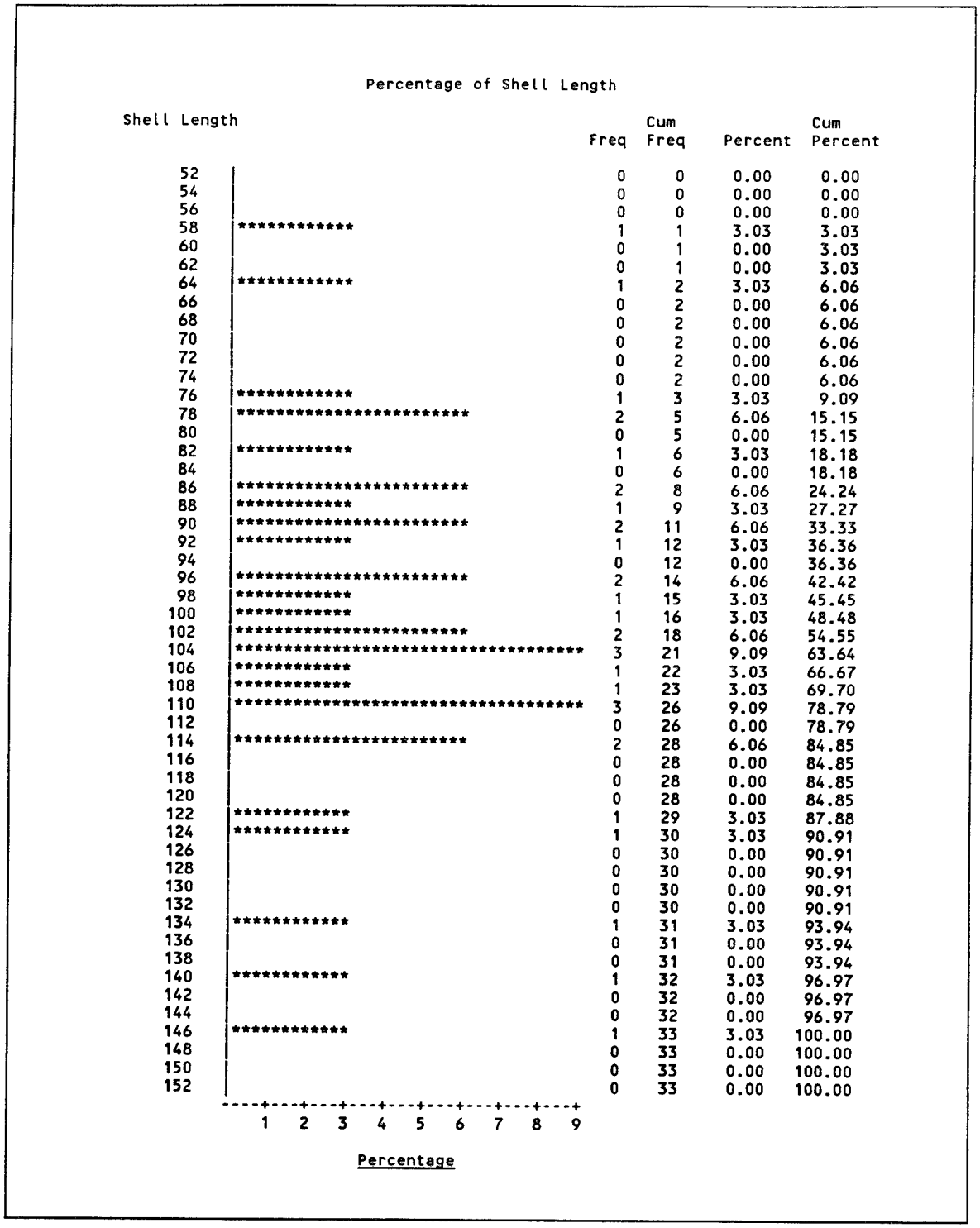


Figure 34. Shell length-frequency histogram for *Megalonaias nervosa* in upper Mississippi River mile 635.2 (Pool 10), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-L buckets of sediment (20 at nearshore site and 20 at a farshore site) (from Miller and Payne, in preparation)

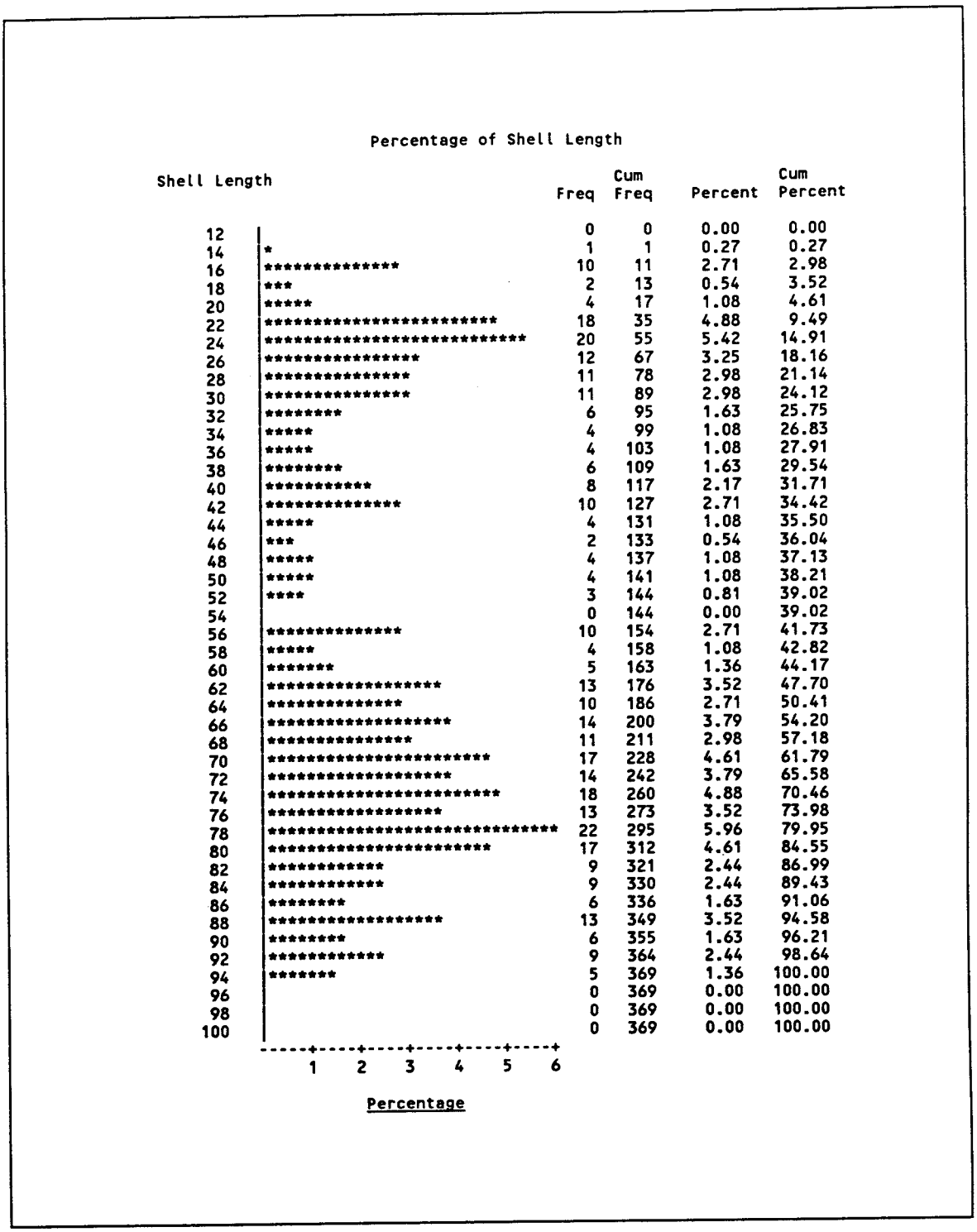


Figure 35. Shell length-frequency histogram for *Amblema plicata plicata* in upper Mississippi River mile 635.2 (Pool 10), nearshore and farshore sites combined, July 1992. Organisms were obtained by having divers collect forty 20-L buckets of sediment (20 at a nearshore site and 20 at a farshore site) (from Miller and Payne, in preparation)

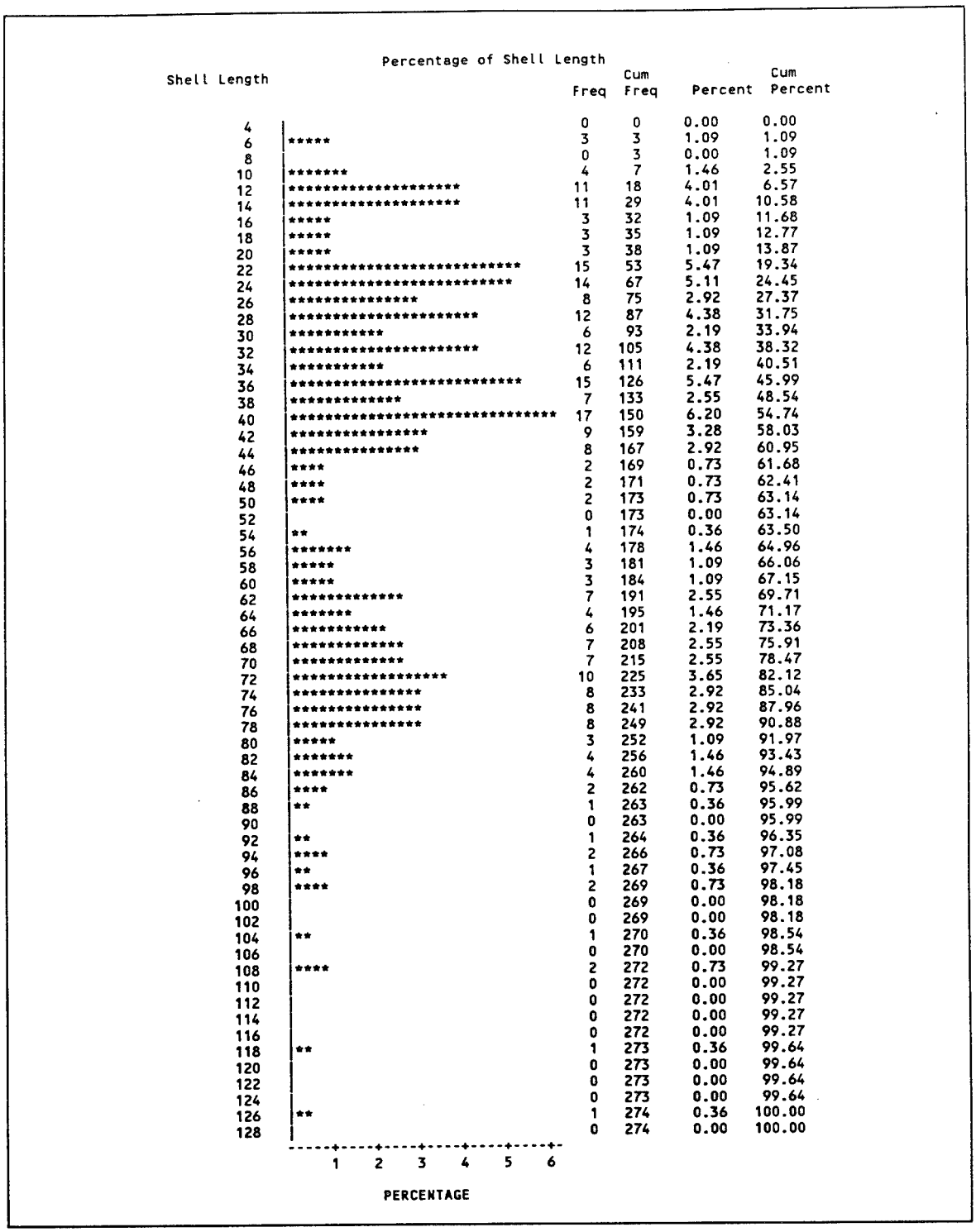


Figure 36. Length-frequency histogram for *Amblema plicata plicata*, lower Tennessee River, August - September 1990 (from Miller, Payne, and Tippit 1992)

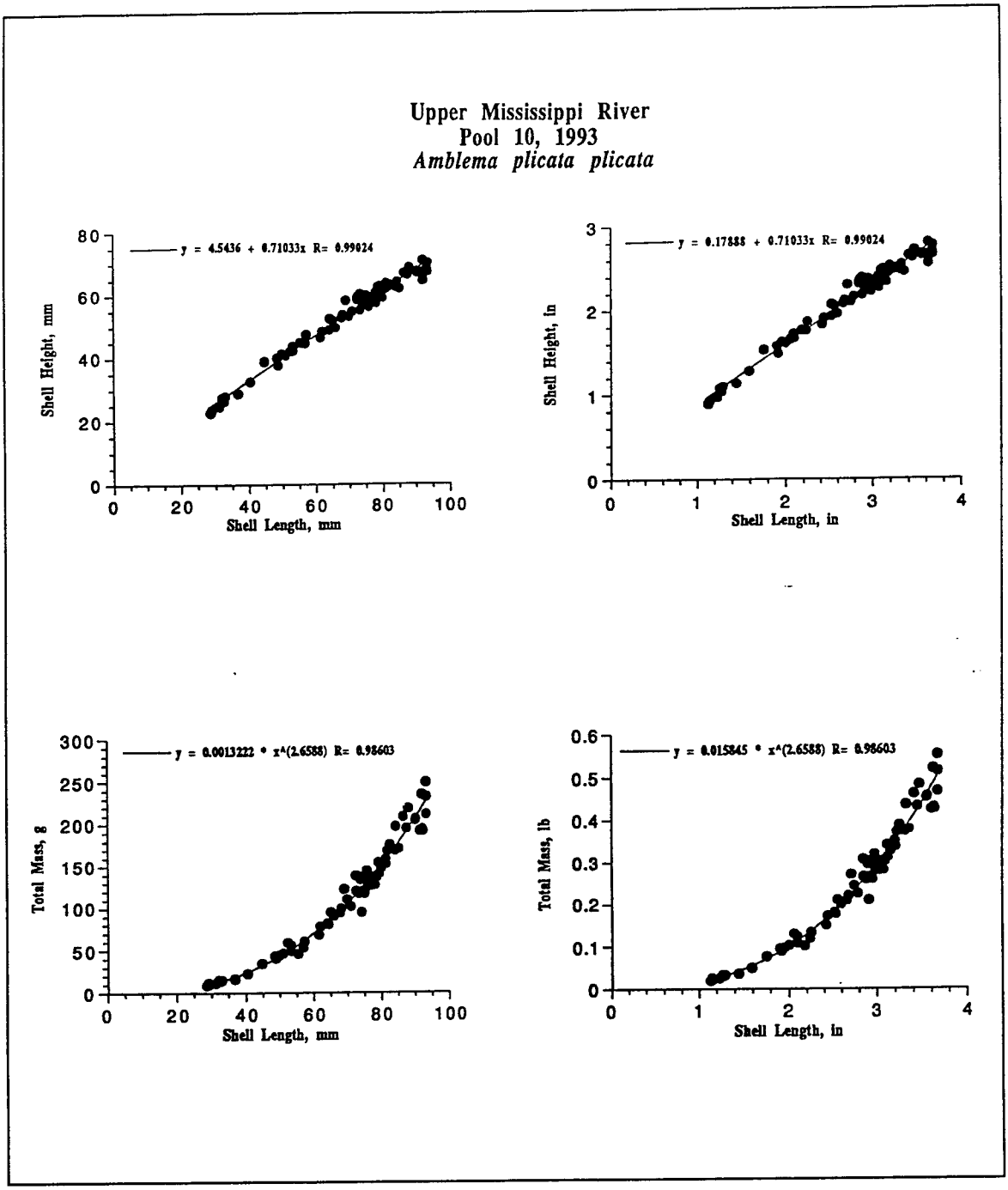


Figure 37. Relationships between shell length and shell height and total mass, in metric and English units, for *Amblema plicata plicata*, upper Mississippi River (Miller and Payne, unpublished information)

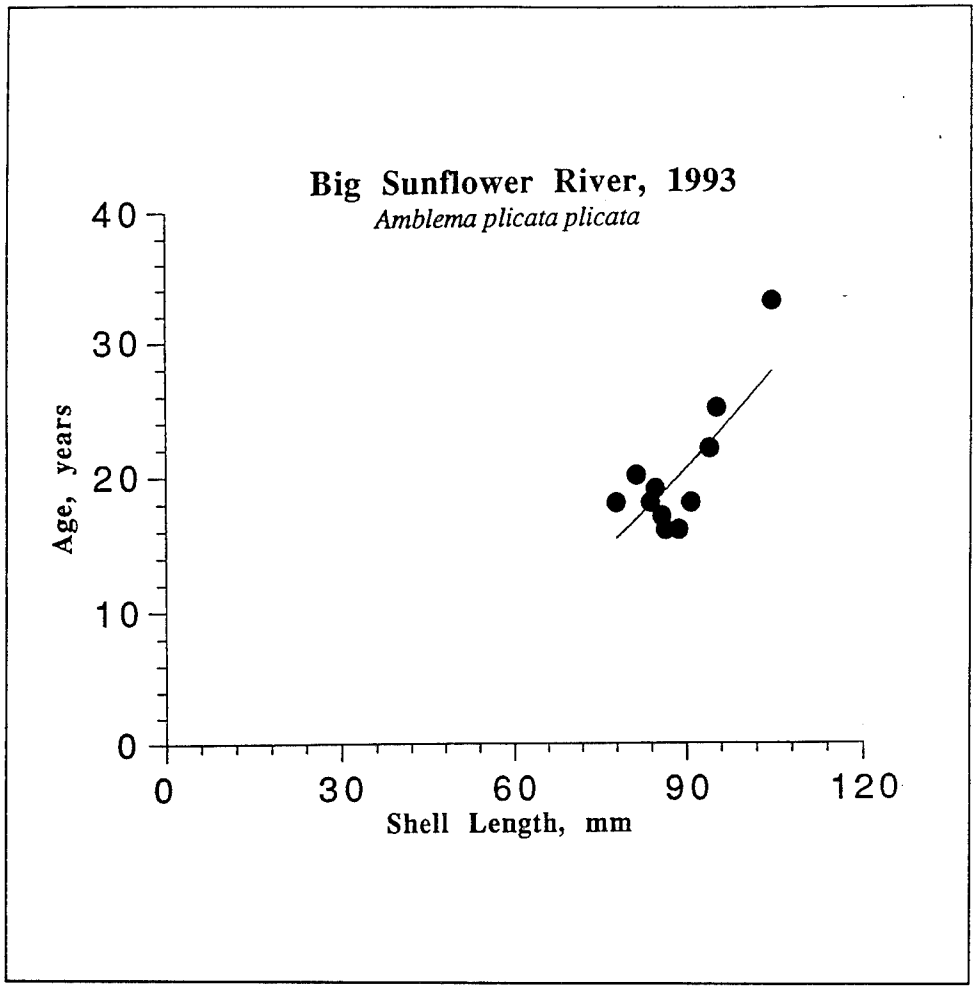


Figure 38. Relationship between age in years and shell length (mm) for *Amblema plicata plicata*, Big Sunflower River, September 1993

Table 1
Summary Information on Collection Sites on Big Sunflower River, Mississippi, 14-18 September 1993

Date	RM	Qualitative Samples				Quantitative Samples			
		No. of Sites	No. of Replicates	Total Samples	Sample Numbers	No. of Sites	No. of Replicates	Total Samples	Sample Numbers
14 Sep	62.2	1	12	12	1,2	2	10	20	1,2
14 Sep	62.2	1	11	11					
15 Sep	34.5	2	12	24	3,4	5	10	50	3,4,5,6,7
16 Sep	35.1	2	12	24	5,6	2	10	20	8,9
16 Sep	34.7	1	12	12	7	2	10	20	10,11
16 Sep	35.2	1	12	12	8				
16 Sep	35.7	1	12	12	9				
17 Sep	35.2	3	12	36	10,11,12	3	10	30	12,13,14
17 Sep	34.6	1	12	12	13	1	10	10	15
17 Sep	34.0	1	12	12	14	1	10	10	16
17 Sep	33.5	1	12	12	15	1	10	10	17
18 Sep	62.3	1	6	6	16				
18 Sep	62.3	1	5	5	17				

(Continued)

Table 1 (Concluded)

Date	RM	Qualitative Samples				Quantitative Samples			
		No. of Sites	No. of Replicates	Total Samples	Sample Numbers	No. of Sites	No. of Replicates	Total Samples	Sample Numbers
18 Sep	66.0	1	5	5	18				
18 Sep	73.8	1	5	5	19				
Total				200				170	

Table 2
Freshwater Bivalves Collected Using Qualitative and Quantitative Methods in Big Sunflower River, 1993

Species	Downriver of Lock and Dam 1		Upriver of Lock and Dam 1
	Qualitative	Quantitative	
Arcidens confragosus (Say, 1829)	X		X
Amblema p. plicata (Say, 1817)	X	X	X
Corbicula fluminea (Muller, 1774)	X		X
Ellipsaria lineolata (Rafinesque, 1820)		X	
Glebula rotundata (Lamarck, 1819)			X
Fusconaia ebena (I. Lea, 1831)	X		
Fusconaia flava (Rafinesque, 1820)	X	X	X
Lampsilis hydiana (I. Lea, 1838)			X
Lampsilis teres (Rafinesque, 1820)	X		X
Leptodea fragilis (Rafinesque, 1820)	X	X	X
Megalonaias nervosa (Rafinesque, 1820)	X	X	X
Obliquaria reflexa Rafinesque, 1820	X	X	X
Plectomerus dombeyanus (Valenciennes, 1827)	X	X	X
Pleurobema pyramidatum (I. Lea, 1840)	X		
Potamilus ohiensis (Rafinesque, 1820)			X
Potamilus pupuratus (Lamarck, 1819)	X	X	X
Pyganodon grandis Say, 1829	X		X
Quadrula p. pustulosa (I. Lea, 1831)	X	X	X
Quadrula quadrula (Rafinesque, 1820)	X	X	X
Quadrula nodulata (Rafinesque, 1820)	X	X	X
Toxolasma texasensis (I. Lea, 1857)			X
Tritogonia verrucosa (Rafinesque, 1820)	X		
Truncilla donaciformis (I. Lea, 1828)			X

(Continued)

Note: The reach upriver of Lock and Dam 1 includes bivalves collected at shallow water sites by nondivers (2,941 specimens, Table D3) as well as specimens collected by divers and nondivers at three locations in September (1,537 specimens, Tables C1-C4). A total of 28 species of freshwater mussels (Family: Unionidae), plus the Asian clam *Corbicula fluminea* were collected during this survey.

Table 2 (Concluded)

Species	Downriver of Lock and Dam 1		Upriver of Lock and Dam 1
	Qualitative	Quantitative	
Truncilla truncata (Rafinesque, 1820)		X	X
Uniomerus declivis (Say, 1831)			X
Uniomerus tetralasmus (Say, 1831)			X
Utterbackia imbecillis (Say, 1829)	X		X
Total species	18	12	23
Total individuals	3,013	2,473	4,478

Table 3
Density (Individuals/sq m) and Biomass (g/sq m) for Freshwater Mussels (Family: Unionidae) Collected at Four Beds in Big Sunflower River, September 1993

Location	Density	SE	Biomass	SE	Number of Samples
Downriver of Holly Bluff Cutoff (DHBC)	28.6[c]	2.8	6,590.8[c]	636.1	80
Upriver of Holly Bluff Cutoff (UHBC)	35.8[bc]	5.0	10,647.4[b]	1,405.0	40
Upriver of Holly Bluff Cutoff-Gravel Bar (UHBC-GB)	49.1[b]	4.4	11,697.8[b]	1,004.9	30
Downriver of Lock and Dam 1 (DL&D1)	235.0[a]	16.0	52,250.1[a]	3,284.8	20
F	196.7		178.56		
Pr > F	0.0001		0.0001		

Note: SE = Standard Error of the Mean. Means with the same superscript are not significantly different based on Duncan's Multiple Range Test ($p > 0.05$). F = F statistic; Pr = probability.

Table 4
Density (Individuals/sq m) and Biomass (g/sq m) for Freshwater Mussels (Family: Unionidae) Collected at Specific Sites at Four Beds in Big Sunflower River, September 1993

Site No.	Density	SE	Biomass	SE	Number of Samples
Downriver of Holly Bluff Cutoff					
3	10.0^{c}	7.0	2,262.1^{d}	1,775.9	10
4	35.6^{b}	8.9	7,676.9^{b}	1,947.4	10
5	64.8^{a}	9.2	14,830.7^{a}	2,169.9	10
6	34.8^{b}	4.6	6,808.2^{bc}	1,127.7	10
7	24.0^{bc}	4.5	6,146.0^{bcd}	1,265.8	10
15	15.6^{c}	3.0	5,417.4^{bcd}	1,101.3	10
16	33.6^{b}	3.0	7,173.4^{b}	704.8	10
17	10.4^{c}	2.1	2,411.6^{cd}	512.0	10
F	9.45		7.4		
Pr > F	0.0001		0.0001		
Upriver of Holly Bluff Cutoff					
8	74.0^{a}	8.9	21,214.6^{a}	2,286.3	10
9	45.2^{b}	5.4	11,415.5^{b}	1,413.2	10
10	2.4^{d}	1.6	497.7^{c}	372.8	10
11	21.6^{c}	3.4	9,461.92^{b}	1,666.2	10
F	31.08		28.49		
Pr > F	0.0001		0.0001		
Gravel Bar Upriver of Holly Bluff Cutoff					
12	46.8^{ab}	6.7	11,143.2^{ab}	1,432.3	10
13	38.4^{b}	7.6	8,710.9^{b}	1,792.7	10
14	62.0^{a}	7.1	15,239.4^{a}	1,441.2	10
F	2.81		4.45		
Pr > F	0.0778		0.0214		
Downriver of Lock and Dam 1					
1	277.2^{a}	24.2	59,088.3^{a}	5,519.5	10
2	192.8^{b}	10.2	45,412.0^{b}	2,168.0	10
F	10.31		5.32		
Pr > F	0.0048		0.0332		

Note: (SE = Standard Error of the Mean). Means with the same superscript are not significantly different based upon Duncan's Multiple Range Test ($p > 0.05$). Pr = probability; F = F statistic.

Table 5
Total Shell Length, Total Wet Mass, Shell Height, and Cumulative Abundance for *Amblema plicata plicata*, All Sites Combined, Big Sunflower River, September - October 1993 (Based on Information in Figure 32)

Shell Length mm	Total Mass g	Total Mass lb	Shell Height mm	Shell Height in.	Abundance %	Cumulative Abundance %
11.5	1.2	0.0	19.1	0.75	0.00	0.00
13.7	1.8	0.0	20.3	0.80	0.00	0.00
15.9	2.6	0.0	21.6	0.85	0.00	0.00
18.1	3.5	0.0	22.9	0.90	0.00	0.00
20.4	4.5	0.0	24.1	0.95	0.05	0.05
22.6	5.8	0.0	25.4	1.00	0.00	0.05
24.8	7.2	0.0	26.7	1.05	0.00	0.05
27.0	8.8	0.0	27.9	1.10	0.00	0.05
29.2	10.5	0.0	29.2	1.15	0.00	0.05
31.4	12.5	0.0	30.5	1.20	0.00	0.05
33.6	14.6	0.0	31.8	1.25	0.00	0.05
35.9	16.9	0.0	33.0	1.30	0.00	0.05
38.1	19.5	0.0	34.3	1.35	0.00	0.05
40.3	22.2	0.0	35.6	1.40	0.00	0.05
42.5	25.2	0.1	36.8	1.45	0.00	0.05
44.7	28.3	0.1	38.1	1.50	0.00	0.05
46.9	31.7	0.1	39.4	1.55	0.00	0.05
49.2	35.3	0.1	40.6	1.60	0.00	0.05
51.4	39.1	0.1	41.9	1.65	0.00	0.05
53.6	43.1	0.1	43.2	1.70	0.05	0.11
55.8	47.4	0.1	44.5	1.75	0.00	0.11
58.0	51.8	0.1	45.7	1.80	0.05	0.16
60.2	56.6	0.1	47.0	1.85	0.00	0.16
62.4	61.5	0.1	48.3	1.90	0.00	0.16
64.7	66.7	0.1	49.5	1.95	0.00	0.16
66.9	72.2	0.2	50.8	2.00	0.00	0.16
69.1	77.8	0.2	52.1	2.05	0.11	0.27

(Continued)

Table 5 (Concluded)

Shell Length mm	Total Mass g	Total Mass lb	Shell Height mm	Shell Height in.	Abundance %	Cumulative Abundance %
71.3	83.8	0.2	53.3	2.10	0.05	0.33
73.5	89.9	0.2	54.6	2.15	0.22	0.55
75.7	96.4	0.2	55.9	2.20	0.93	1.48
78.0	103.0	0.2	57.2	2.25	1.31	2.79
80.2	110.0	0.2	58.4	2.30	2.52	5.31
82.4	117.2	0.3	59.7	2.35	6.19	11.49
84.6	124.6	0.3	61.0	2.40	8.98	20.47
86.8	132.4	0.3	62.2	2.45	12.75	33.22
89.0	140.3	0.3	63.5	2.50	15.65	48.88
91.2	148.6	0.3	64.8	2.55	15.16	64.04
93.5	157.1	0.3	66.0	2.60	14.18	78.22
95.7	165.9	0.4	67.3	2.65	9.63	87.85
97.9	175.0	0.4	68.6	2.70	6.79	94.64
100.1	184.3	0.4	69.9	2.75	2.90	97.54
102.3	194.0	0.4	71.1	2.80	1.53	99.07
104.5	203.9	0.4	72.4	2.85	0.55	99.62
106.8	214.0	0.5	73.7	2.90	0.27	99.89
109.0	224.5	0.5	74.9	2.95	0.00	99.89
111.2	235.3	0.5	76.2	3.00	0.00	99.89
113.4	246.3	0.5	77.5	3.05	0.05	99.95
115.6	257.7	0.6	78.7	3.10	0.00	99.95
117.8	269.3	0.6	80.0	3.15	0.00	99.95
120.0	281.2	0.6	81.3	3.20	0.00	99.95
122.3	293.4	0.6	82.6	3.25	0.05	100.00

Table 6
Total Shell Length, Total Wet Mass, Shell Height, and Cumulative Abundance for *Megalonaias nervosa*, All Sites Combined, Big Sunflower River, September - October 1993 (based on information in Figure 33)

Shell Length mm	Total Mass g	Total Mass lb	Shell Height mm	Shell Height in.	Abundance %	Cumulative Abundance %
56.1	39.0	0.1	43.2	1.70	0.00	0.00
58.0	42.9	0.1	44.5	1.75	1.30	1.30
60.0	47.0	0.1	45.7	1.80	0.00	1.30
61.9	51.4	0.1	47.0	1.85	0.00	1.30
63.9	56.0	0.1	48.3	1.90	0.00	1.30
65.8	60.9	0.1	49.5	1.95	0.00	1.30
67.8	66.0	0.1	50.8	2.00	0.00	1.30
69.7	71.4	0.2	52.1	2.05	0.00	1.30
71.7	77.1	0.2	53.3	2.10	0.00	1.30
73.6	83.1	0.2	54.6	2.15	0.00	1.30
75.6	89.4	0.2	55.9	2.20	0.00	1.30
77.5	95.9	0.2	57.2	2.25	0.00	1.30
79.4	102.8	0.2	58.4	2.30	0.00	1.30
81.4	109.9	0.2	59.7	2.35	0.00	1.30
83.3	117.4	0.3	61.0	2.40	0.00	1.30
85.3	125.2	0.3	62.2	2.45	0.00	1.30
87.2	133.3	0.3	63.5	2.50	0.00	1.30
89.2	141.8	0.3	64.8	2.55	1.30	2.60
91.1	150.5	0.3	66.0	2.60	0.00	2.60
93.1	159.7	0.4	67.3	2.65	1.30	3.90
95.0	169.1	0.4	68.6	2.70	0.00	3.90
97.0	178.9	0.4	69.9	2.75	0.00	3.90
98.9	189.1	0.4	71.1	2.80	1.30	5.19
100.9	199.7	0.4	72.4	2.85	0.00	5.19
102.8	210.6	0.5	73.7	2.90	0.00	5.19
104.7	221.9	0.5	74.9	2.95	1.30	6.49
106.7	233.5	0.5	76.2	3.00	0.00	6.49
108.6	245.6	0.5	77.5	3.05	1.30	7.79

(Continued)

Table 6 (Concluded)

Shell Length mm	Total Mass g	Total Mass lb	Shell Height mm	Shell Height in.	Abundance %	Cumulative Abundance %
110.6	258.0	0.6	78.7	3.10	2.60	10.39
112.5	270.9	0.6	80.0	3.15	2.60	12.99
114.5	284.1	0.6	81.3	3.20	2.60	15.58
116.4	297.7	0.7	82.6	3.25	2.60	18.18
118.4	311.8	0.7	83.8	3.30	2.60	20.78
120.3	326.3	0.7	85.1	3.35	2.60	23.38
122.3	341.2	0.8	86.4	3.40	6.49	29.87
124.2	356.5	0.8	87.6	3.45	5.19	35.06
126.1	372.3	0.8	88.9	3.50	5.19	40.26
128.1	388.5	0.9	90.2	3.55	7.79	48.05
130.0	405.2	0.9	91.4	3.60	9.09	57.14
132.0	422.3	0.9	92.7	3.65	7.79	64.94
133.9	439.8	1.0	94.0	3.70	5.19	70.13
135.9	457.8	1.0	95.3	3.75	2.60	72.73
137.8	476.3	1.1	96.5	3.80	3.90	76.62
139.8	495.3	1.1	97.8	3.85	1.30	77.92
141.7	514.7	1.1	99.1	3.90	2.60	80.52
143.7	534.6	1.2	100.3	3.95	6.49	87.01
145.6	555.0	1.2	101.6	4.00	2.60	89.61
147.6	575.9	1.3	102.9	4.05	3.90	93.51
149.5	597.3	1.3	104.1	4.10	1.30	94.81
151.4	619.2	1.4	105.4	4.15	1.30	96.10
153.4	641.6	1.4	106.7	4.20	1.30	97.40
155.3	664.6	1.5	108.0	4.25	2.60	100.00
157.3	688.0	1.5	109.2	4.30	0.00	100.00

Table 7
Estimate of Economic Value of Two Species of Freshwater Mussels in Selected Reaches of Big Sunflower River. These Estimates Are Based on Mussel Sizes, Weights, and Densities Measured in Fall of 1993 (see text for additional assumptions)

Amblema plicata plicata (Threeridge)

Location	Total Mussel Density	Abund %	Species Density	Market-able, %	Mean Mass g/Ind[1]	Total Mass g/sq m	Total Mass lb/sq yd	Total Value $/sq m	Total Value $/sq yd	Size of Mussel Bed			Totals for *A. p. plicata*		
										Length m	Width m	Total, m^2	Total Mass, lb	Total Dollar Value	%
DHBC	26.8	49.1	13.2	36.0	168.1	796.7	1.5	1.76	1.47	1,609	61	98,167	172,416	172,416	12.39
UHBC	35.8	56.4	20.2	36.0	168.1	1,222.1	2.3	2.69	2.25	3,219	61	196,335	528,984	528,984	38.00
UHBC-GB	49.1	77.7	38.2	36.0	168.1	2,308.9	4.3	5.09	4.26	500	61	30,500	155,254	155,254	11.15
DL&D1	235.0	90.0	211.6	36.0	168.1	12,802.5	23.6	28.22	23.60	100	61	6,100	172,172	172,172	12.37
UL&D1-SH	5.5	21.3	1.2	36.0	168.1	70.8	0.1	0.16	0.13	33,473	10	334,734	52,284	52,284	3.76
UL&D1-DP	3.7	47.1	1.7	36.0	168.1	105.3	0.2	0.23	0.19	33,473	40	1,338,936	310,921	310,921	22.34
									Total	72,375	294	2,004,772	1,392,031	1,392,031	100.00

(Sheet 1 of 3)

[1] g/Ind - grams/individual.

Table 7 (Continued)

Megalonaias nervosa (Washboard)

Location	Total Mussel Density	Abund %	Species Density	Market-able, %	Mean Mass g/Ind	Total Mass g/sq m	Total Mass lb/sq yd	Total Value $/sq m	Total Value $/sq yd	Size of Mussel Bed			Totals for *M. nervosa*		
										Length m	Width m	Total m^2	Total Mass, lb	Total Dollar Value	%
DHBC	26.8	7.9	2.1	84.2	438.8	779.3	1.4	1.72	1.44	1,609	61	98,167	168,656	168,656	12.61
UHBC	35.8	6.4	2.3	84.2	438.8	849.2	1.6	1.87	1.57	3,219	61	196,335	365,570	365,570	27.47
UHBC-GB	49.1	1.9	0.9	84.2	438.8	348.3	0.6	0.77	0.64	500	61	30,500	23,421	23,421	1.75
DL&D1	235.0	0.2	0.4	84.2	438.8	147.6	0.3	0.33	0.27	100	61	6,100	1,985	1,985	0.15
UL&D1-SH	5.5	3.6	0.2	84.2	438.8	73.2	0.1	0.16	0.13	33,473	10	334,734	53,987	53,987	4.04
UL&D1-DP	3.7	17.9	0.7	84.2	438.8	244.7	0.5	0.54	0.45	33,473	40	1,338,936	722,337	722,337	53.99
									Total	72,375	294	2,004,772	1,337,956	1,337,956	100.00

Price/lb, live weight - $1.00
Multiply sq m to obtain sq yd - 1.196
Multiply lb to obtain g - 453.59
Upriver of Lock and Dam 1:
RM 62.2 - 83.0 (20.8 miles or 33,473.4 m)
Marketable Sizes (Shell Height)
Threeridge - 2.625 in. and greater
Washboard - 3.25 in. and greater

Table 7 (Concluded)

Grand Total for Both Species
Total Mass - 2,729,987 grams
Dollar Value - $2,729,987
DHBC - Immediately downriver of Holly Bluff Cutoff (RM 34.7 - 33.7)
UHBC - Immediately upriver of Holly Bluff Cutoff (RM 34.7 - 35.2)
UHBC-GB - Gravel Bar upriver of Holly Bluff Cutoff (RM 35.2)
DL&D1 - Immediately downriver of Lock and Dam 1 (RM 62)
UL&D1-SH - Shallow water sites upriver of Lock and Dam 1 (RM 62.2 - 83.0)
UL&D1-DP - Deep water sites upriver of Lock and Dam 1 (RM 62.2 - 83.0)

Appendix A Mussels Collected Using Qualitative Methods, Big Sunflower River, Mississippi, 1993

Table A1
Percent Abundance of Freshwater Mussels (Unionidae) Collected Using Qualitative Methods at Four Locations in Big Sunflower River, Mississippi, 1993 (HBC = Holly Bluff Cutoff)

Species	Downriver of HBC	Upriver of HBC	Gravel Bar	Downriver of L and D No. 1	Total
A. p. plicata	63.25	64.61	67.73	91.09	68.34
P. dombeyanus	17.81	23.24	21.85	3.96	18.62
Q. p. pustulosa	9.62	4.24	4.03	3.22	5.81
Q. quadrula	4.50	0.87	1.51	0.00	2.06
O. reflexa	0.61	1.16	2.69	0.00	1.13
M. nervosa	1.94	0.77	1.01	0.00	1.10
F. flava	1.13	1.64	0.17	0.00	0.96
P. purpuratus	0.20	1.83	0.17	0.25	0.76
L. fragilis	0.10	0.68	0.17	0.50	0.37
Q. nodulata	0.10	0.19	0.50	0.50	0.27
A. confragosus	0.31	0.19	0.00	0.00	0.17
L. teres	0.00	0.29	0.17	0.00	0.13
P. pyramidatum	0.10	0.10	0.00	0.25	0.10
P. grandis	0.10	0.10	0.00	0.00	0.07
T. verrucosa	0.10	0.10	0.00	0.00	0.07
U. imbecillis	0.00	0.00	0.00	0.25	0.03
F. ebena	0.10	0.00	0.00	0.00	0.03
Total individuals	977	1,037	595	404	3,013
Total species	15	15	11	8	17
Menhinick's Index	0.48	0.47	0.45	0.40	0.31
Species diversity (H')	1.19	1.12	1.00	0.42	1.08
Evenness	0.55	0.54	0.56	0.39	0.50
Simpson's Dominance	0.44	0.47	0.51	0.83	0.51

Table A2
Percent Occurrence of Freshwater Mussels Collected Using Qualitative Methods at Four Locations in Big Sunflower River, Mississippi, September 1993 (HBC = Holly Bluff Cutoff)

Species	Downriver of HBC	Upriver of HBC	Gravel Bar	Downriver of L and D No. 1	Total
A. p. plicata	98.33	100.00	94.44	100.00	98.32
P. dombeyanus	61.67	80.00	80.56	43.48	69.27
Q. p. pustulosa	71.67	41.67	47.22	34.78	51.96
Q. quadrula	31.67	10.00	19.44	0.00	17.88
O. reflexa	5.00	18.33	27.78	0.00	13.41
F. flava	13.33	20.00	2.78	0.00	11.73
M. nervosa	18.33	8.33	8.33	0.00	10.61
P. purpuratus	3.33	16.67	2.78	4.35	7.82
L. fragilis	1.67	10.00	2.78	4.35	5.03
Q. nodulata	1.67	3.33	8.33	8.70	4.47
A. confragosus	5.00	3.33	0.00	0.00	2.79
L. teres	0.00	5.00	2.78	0.00	2.23
P. pyramidatum	1.67	1.67	0.00	4.35	1.68
P. grandis	1.67	1.67	0.00	0.00	1.12
T. verrucosa	1.67	1.67	0.00	0.00	1.12
U. imbecillis	0.00	0.00	0.00	4.35	0.56
F. ebena	1.67	0.00	0.00	0.00	0.56
Total samples	60	60	36	23	179

Appendix B
Mussels Collected Using Quantitative Methods, Big Sunflower River, Mississippi, 1993

Table B1
Percent Abundance of Freshwater Mussels Collected Using Quantitative Methods at Eight Sites Immediately Downriver of Holly Bluff Cuffoff, Big Sunflower River, 1993

Species	Site Number								Total
	3	4	5	6	7	15	16	17	
A. p. plicata	72.00	92.13	50.00	31.03	38.33	10.26	35.71	61.54	49.13
Q. p. pustulosa	16.00	6.74	22.22	42.53	20.00	2.56	15.48	7.69	19.41
P. dombeyanus	4.00	1.12	6.74	10.34	23.33	66.67	21.43	26.92	15.21
M. nervosa	4.00	0.00	12.96	9.20	13.33	5.13	5.95	0.00	7.87
Q. quadrula	0.00	0.00	6.79	1.15	3.33	12.82	2.38	0.00	3.67
F. flava	4.00	0.00	1.23	4.60	0.00	0.00	10.71	3.85	2.97
O. reflexa	0.00	0.00	0.00	0.00	0.00	2.56	7.14	0.00	1.22
Q. nodulata	0.00	0.00	0.00	1.15	1.67	0.00	0.00	0.00	0.35
P. purpuratus	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.00	0.17
Total individuals	25	89	162	87	60	39	84	26	572
Total species	5	3	6	7	6	6	8	4	9
Menhinick's Index	1.00	0.32	0.47	0.75	0.77	0.96	0.87	0.78	0.38

(Continued)

Table B1 (Concluded)

Species	Site Number								Total
	3	4	5	6	7	15	16	17	
Species diversity (H')	0.92	0.31	1.36	1.42	1.48	1.11	1.72	0.97	1.46
Evenness	0.59	0.48	0.72	0.77	0.89	0.58	0.82	0.78	0.67
Simpson's Dominance	0.53	0.85	0.32	0.29	0.25	0.46	0.21	0.44	0.31
% Individuals < 30 mm	0.00	0.00	0.00	1.15	1.67	0.00	0.00	0.00	0.35
% Species < 30 mm	0.00	0.00	0.00	14.29	16.67	0.00	0.00	0.00	22.22

Table B2
Percent Occurrence of Freshwater Mussels Collected Using Quantitative Methods at Eight Sites Immediately Downriver of Holly Bluff Cutoff, Big Sunflower River, 1993

Species	Site Number								Total
	3	4	5	6	7	15	16	17	
A. p. plicata	40.0	100.0	90.0	70.0	100.0	10.0	90.0	90.0	73.8
P. dombeyanus	10.0	10.0	50.0	60.0	70.0	80.0	90.0	60.0	53.8
Q. p. pustulosa	30.0	30.0	90.0	100.0	70.0	10.0	60.0	20.0	51.3
M. nervosa	10.0	0.0	90.0	50.0	40.0	20.0	50.0	0.0	32.5
Q. quadrula	0.0	0.0	70.0	10.0	20.0	40.0	20.0	0.0	20.0
F. flava	10.0	0.0	20.0	40.0	0.0	0.0	70.0	10.0	18.8
O. reflexa	0.0	0.0	0.0	0.0	0.0	10.0	40.0	0.0	6.3
Q. nodulata	0.0	0.0	0.0	10.0	10.0	0.0	0.0	0.0	2.5
P. purpuratus	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	1.3
Total samples	10	10	10	10	10	10	10	10	80

Table B3
Percent Abundance of Freshwater Bivalves Collected Using Quantitative Methods at Four Sites Upriver of Holly Bluff Cutoff, Big Sunflower River, September 1993

Species	Site Number				Total
	8	9	10	11	
A. p. plicata	64.86	52.21	83.33	33.33	56.42
P. dombeyanus	25.95	25.66	0.00	50.00	29.05
F. flava	2.16	4.42	0.00	0.00	2.51
M. nervosa	4.32	7.08	0.00	12.96	6.42
Q. p. pustulosa	1.08	4.42	0.00	0.00	1.96
O. reflexa	1.08	4.42	0.00	0.00	1.96
P. purpuratus	0.00	0.00	0.00	3.70	0.56
Q. nodulata	0.54	0.88	0.00	0.00	0.56
Q. quadrula	0.00	0.88	0.00	0.00	0.28
L. fragilis	0.00	0.00	16.67	0.00	0.28
Total individuals	185	113	6	54	358
Total species	7	8	2	4	10

(Continued)

Table B3 (Concluded)

Species	Site Number				Total
	8	9	10	11	
Species diversity (H')	0.98	1.37	0.45	1.09	1.19
Evenness	0.63	0.65	0.88	0.86	0.63
Simpson's Dominance	0.49	0.34	0.67	0.37	0.41
Menhinick's Index	0.51	0.75	0.82	0.54	0.53
% Individuals < 30 mm	0.54	0.00	0.00	0.00	0.28
% Species < 30 mm	14.28	0.00	0.00	0.00	10.00

Table B4
Percent Occurrence of Freshwater Bivalves Collected Using Quantitative Methods at Four Sites Upriver of Holly Bluff Cutoff, Big Sunflower River, September 1993

Species	Site Number				
	8	9	10	11	Total
A. p. plicata	100.0	100.0	20.0	100.0	80.0
P. dombeyanus	100.0	100.0	0.0	90.0	72.5
F. flava	30.0	50.0	0.0	0.0	20.0
M. nervosa	60.0	50.0	0.0	40.0	37.5
Q. p. pustulosa	20.0	50.0	0.0	0.0	17.5
O. reflexa	20.0	50.0	0.0	0.0	17.5
P. purpuratus	0.0	0.0	0.0	20.0	5.0
Q. nodulata	10.0	10.0	0.0	0.0	5.0
Q. quadrula	0.0	10.0	0.0	0.0	2.5
L. fragilis	0.0	0.0	10.0	0.0	2.5
Total samples	10	10	10	10	40

Table B5
Percent Abundance of Freshwater Mussels Species Collected Using Quantitative Methods at Three Sites at a Gravel Bar Located Upriver of Holly Bluff Cutoff, Big Sunflower River, September 1993

Species	Site Number			
	12	13	14	Total
A. p. plicata	84.62	72.92	75.48	77.72
P. dombeyanus	4.27	6.25	13.55	8.70
Q. p. pustulosa	3.42	5.21	3.23	3.80
Q. quadrula	1.71	3.13	4.52	3.26
O. reflexa	0.00	6.25	1.94	2.45
M. nervosa	3.42	1.04	1.29	1.90
L. fragilis	1.71	1.04	0.00	0.82
F. flava	0.85	1.04	0.00	0.54
E. lineolata	0.00	1.04	0.00	0.27
Q. nodulata	0.00	1.04	0.00	0.27
P. pyramidatum	0.00	1.04	0.00	0.27
Total individuals	117	96	155	368
Total species	7	11	6	11
Menhinick's Index	0.65	1.12	0.48	0.57
Species diversity (H')	0.69	1.12	0.87	0.93
Evenness	0.40	0.41	0.51	0.41
Simpson's dominance	0.72	0.54	0.59	0.61
% Individuals < 30 mm	0.85	0.00	0.00	0.27
% Species < 30 mm	14.28	0.00	0.00	9.09

Table B6
Percent Occurrence of Freshwater Mussels Collected Using Quantitative Methods at Three Sites at a Gravel Bar Upriver of Holly Bluff Cutoff, Big Sunflower River, September 1993

Species	Site Number			
	12	13	14	Total
A. p. plicata	100.0	90.0	100.0	96.7
P. dombeyanus	50.0	40.0	100.0	63.3
Q. p. pustulosa	30.0	40.0	50.0	40.0
Q. quadrula	20.0	20.0	60.0	33.3
O. reflexa	0.0	30.0	30.0	20.0
M. nervosa	40.0	10.0	20.0	23.3
L. fragilis	20.0	10.0	0.0	10.0
F. flava	10.0	10.0	0.0	6.7
E. lineolata	0.0	10.0	0.0	3.3
Q. nodulata	0.0	10.0	0.0	3.3
P. pyramidatum	0.0	10.0	0.0	3.3
Total samples	10	10	10	30

Table B7
Percent Abundance of Freshwater Mussels Collected Using Quantitative Methods Immediately Downriver of Lock and Dam 1, Big Sunflower River, 1993

Species	Site Number		Total
	1	2	
A. p. plicata	92.35	86.72	90.04
Q. p. pustulosa	2.89	4.36	3.49
O. reflexa	1.88	0.62	1.36
P. dombeyanus	1.30	6.64	3.49
Q. nodulata	0.72	0.00	0.43
Q. quadrula	0.14	0.83	0.43
T. truncata	0.14	0.00	0.09
F. flava	0.14	0.00	0.09
P. purpuratus	0.14	0.21	0.17
M. nervosa	0.14	0.21	0.17
P. pyramidatum	0.14	0.21	0.17
F. ebena	0.00	0.21	0.09
Total individuals	693	482	1,175
Total species	11	9	12
Menhinick's Index	0.42	0.41	0.35
Species diversity (H')	0.40	0.56	0.49
Evenness	0.35	0.42	0.37
Simpson's Dominance	0.85	0.76	0.81
% Individuals < 30 mm	0.00	0.00	0.00
% Species < 30 mm	0.00	0.00	0.00

Table B8
Percent Occurrence of Freshwater Mussels Collected Using Quantitative Methods Immediately Downriver of Lock and Dam 1, Big Sunflower River, 1993

Species	Site Number		Total
	1	2	
A. p. plicata	100.0	100.0	100.0
Q. p. pustulosa	90.0	90.0	90.0
O. reflexa	50.0	20.0	35.0
P. dombeyanus	60.0	100.0	80.0
Q. nodulata	30.0	0.0	15.0
Q. quadrula	10.0	20.0	15.0
T. truncata	10.0	0.0	5.0
F. flava	10.0	0.0	5.0
P. purpuratus	10.0	10.0	10.0
M. nervosa	10.0	10.0	10.0
P. pyramidatum	10.0	10.0	10.0
F. ebena	0.0	10.0	5.0
Total samples	10	10	20

Appendix C
Mussels Collected Immediately Upriver of Abandoned Lock and Dam 1 Using Qualitative Methods, 18 September 1993, Big Sunflower River, Mississippi

Table C1
Percent Abundance of Freshwater Bivalves Collected Using Qualitative Methods at Four Depths in Big Sunflower River, Immediately Downriver of Highway 12 Bridge (RM 62.3), 18 September 1993

Species	Depth, m				Total
	0.6	0.6 to 1.2	1.5	1.8	
P. dombeyanus	72.13	35.42	4.00	0.00	33.88
A. p. plicata	17.21	27.08	16.00	57.50	33.06
Q. nodulata	0.00	1.04	0.00	20.83	7.16
M. nervosa	0.00	10.42	60.00	0.00	6.89
P. grandis	2.46	9.38	8.00	0.00	3.86
Q. p. pustulosa	0.82	3.13	0.00	5.83	3.03
Q. quadrula	0.00	1.04	0.00	6.67	2.48
G. rotundata	4.92	2.08	0.00	0.00	2.20
P. purpuratus	0.00	3.13	12.00	0.83	1.93
L. teres	2.46	3.13	0.00	0.00	1.65
O. reflexa	0.00	0.00	0.00	4.17	1.38
A. confragosus	0.00	2.08	0.00	0.00	0.55
L. fragilis	0.00	0.00	0.00	1.67	0.55
P. ohiensis	0.00	0.00	0.00	0.83	0.28
C. fluminea	0.00	0.00	0.00	0.83	0.28
F. flava	0.00	1.04	0.00	0.83	0.55
L. hydiana	0.00	1.04	0.00	0.00	0.28
Total individuals	122	96	25	120	363
Total species	6	13	5	10	17
Time, min	14	22	20	60	116
Distance, ft	40	150	150	600	940
Bivalves/m	10.0	2.1	0.5	0.7	
Bivalves/min	8.7	4.4	1.3	2.0	

Note: Three nondivers collected at 0.6-, 0.6- to 1.2-, and 1.5-m depths, and three divers collected at 1.8-m depth. A total of six samples were collected. Bivalves were collected by searching the substratum by feel and picking up all live bivalves encountered by touch.

Table C2
Percent Abundance of Freshwater Bivalves Collected Using Qualitative Methods at Four Depths in Big Sunflower River, Immediately Downriver of Highway 12 Bridge (RM 62.3) and Immediately Upriver of Site Presented in Table C1, 18 September 1993

Species	Depth, m				
	0.6	0.6 to 1.2	1.5	1.8	Total
P. dombeyanus	79.29	9.80	0.00	2.04	30.73
M. nervosa	0.00	35.29	66.32	20.41	26.30
A. p. plicata	13.57	19.61	11.58	48.98	22.92
Q. nodulata	0.00	3.92	7.37	9.18	4.69
P. purpuratus	0.71	17.65	5.26	3.06	4.69
Q. quadrula	0.00	7.84	3.16	10.20	4.43
Q. p. pustulosa	1.43	1.96	0.00	3.06	1.56
L. teres	3.57	0.00	0.00	0.00	1.30
P. grandis	0.00	1.96	3.16	1.02	1.30
L. fragilis	0.00	0.00	2.11	1.02	0.78
G. rotundata	1.43	0.00	0.00	0.00	0.52
O. reflexa	0.00	0.00	1.05	0.00	0.26
T. truncata	0.00	0.00	0.00	1.02	0.26
A. confragosus	0.00	1.96	0.00	0.00	0.26
Total bivalves	140	51	95	98	384
Total species	6	9	8	10	14
Time, min	18	16.5	20	44	98.5
Distance, ft	35	100	155	310	600
Bivalves/m	13.1	1.7	2.0	1.0	
Bivalves/min	7.8	3.1	4.8	2.2	

Note: Two nondivers collected at 0.6- and at 0.6- to 1.2-m depths. One diver collected at 1.5 m, and two divers collected at 1.8 m. A total of five samples were collected.

Table C3
Percent Abundance of Freshwater Bivalves Collected Using Qualitative Methods at Four Depths in Big Sunflower River (RM 66.0), 18 September 1993

Species	Depth, m				
	0.6	0.6 to 1.2	1.5	1.8	Total
A. p. plicata	22.90	47.37	35.48	55.05	39.15
P. dombeyanus	70.99	25.00	16.13	8.26	34.66
M. nervosa	0.00	5.26	17.74	2.75	4.76
P. purpuratus	0.00	7.89	12.90	2.75	4.50
Q. nodulata	0.00	0.00	1.61	13.76	4.23
Q. p. pustulosa	0.00	5.26	4.84	5.50	3.44
L. teres	3.82	2.63	3.23	0.00	2.38
P. grandis	1.53	2.63	4.84	0.92	2.12
Q. quadrula	0.00	0.00	0.00	3.67	1.06
F. flava	0.00	0.00	1.61	2.75	1.06
O. reflexa	0.00	0.00	0.00	2.75	0.79
G. rotundata	0.00	2.63	0.00	0.00	0.53
L. fragilis	0.76	0.00	1.61	0.00	0.53
T. donaciformis	0.00	0.00	0.00	0.92	0.26
T. truncata	0.00	0.00	0.00	0.92	0.26
P. ohiensis	0.00	1.32	0.00	0.00	0.26
Total bivalves	131	76	62	109	378
Total species	5	9	10	12	16
Time, min	15	15.1	13	40	83.1
Distance, ft	35	100	100	100	335
Bivalves/m	3.3	3.3	3.3	3.6	
Bivalves/min	8.7	5.0	4.8	2.7	

Note: Two nondivers collected at 0.6 and 0.6 to 1.2 m. One diver collected at 1.8 m, and two divers collected at 1.8 m. A total of five samples were collected.

Table C4
Percent Abundance of Freshwater Bivalves Collected Using Qualitative Methods at Four Depths in Big Sunflower River (RM 73.8), 18 September 1993

Species	Depth, m				
	0.6	0.6 to 1.2	1.5	1.8	Total
A. p. plicata	15.38	20.83	13.71	80.19	47.33
P. dombeyanus	63.08	50.00	69.35	1.89	34.71
P. purpuratus	9.23	0.00	5.65	0.00	3.16
Q. p. pustulosa	0.00	4.17	0.81	6.60	2.43
O. reflexa	1.54	0.00	0.00	0.94	1.94
G. rotundata	6.15	8.33	1.61	0.00	1.94
Q. quadrula	0.00	0.00	0.81	3.77	1.46
Q. nodulata	0.00	0.00	0.00	5.66	1.46
L. teres	4.62	8.33	0.81	0.00	1.46
M. nervosa	0.00	0.00	2.42	0.00	0.97
L. fragilis	0.00	0.00	2.42	0.00	0.97
F. flava	0.00	0.00	0.00	0.94	0.97
A. confragosus	0.00	0.00	2.42	0.00	0.73
P. ohiensis	0.00	4.17	0.00	0.00	0.24
P. grandis	0.00	4.17	0.00	0.00	0.24
Total bivalves	65	24	124	199	412
Total species	6	7	10	7	15
Time, min	16	15.5	14	30	75.5
Distance, ft	100	80	25	40	245
Bivalves/m	3.3	3.3	3.3	16.3	
Bivalves/min	4.1	1.5	8.9	6.6	

Note: Two nondivers collected at 0.6 and 0.6 to 1.2 m. One diver collected at 1.5 m, and two divers collected at 1.8 m. A total of five samples were collected.

Appendix D
Mussels Collected at Shallow Water Sites by Nondivers Using Qualitative Methods Upriver of Abandoned Lock and Dam 1, 1993

Table D1
Freshwater Bivalves Collected in Shallow Water at Selected Sites in Percent Abundance of Big Sunflower River, Mississippi, in Fall of 1993

Species	River Mile								
	62.2	62.9	65.0	65.5	65.5	66.0	67.4	70.4	71.0
P. dombeyanus	77.27	84.73	30.36	77.46	77.78	76.28	44.00	59.12	52.63
A. p. plicata	4.55	9.92	28.57	17.84	18.22	17.95	16.00	25.55	14.47
L. teres	4.55	3.05	3.57	2.35	1.33	3.21	16.00	1.46	15.79
M. nervosa	0.00	0.00	0.00	0.00	0.89	0.64	0.00	8.03	3.95
P. grandis	4.55	0.76	14.29	0.94	0.44	0.00	4.00	2.92	3.95
G. rotundata	0.00	0.76	8.93	0.00	0.00	0.64	8.00	2.92	5.26
P. purpuratus	0.00	0.00	7.14	0.00	0.00	0.00	4.00	0.00	0.00
Q. p. pustulosa	0.00	0.00	3.57	1.41	0.89	0.00	0.00	0.00	1.32
F. flava	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00
A. confragosus	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. fragilis	4.55	0.00	0.00	0.00	0.44	0.00	8.00	0.00	1.32
Q. quadrula	4.55	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00
Q. nodulata	0.00	0.00	1.79	0.00	0.00	0.00	0.00	0.00	0.00
T. texasensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32
O. reflexa	0.00	0.00	1.79	0.00	0.00	0.00	0.00	0.00	0.00
P. ohiensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. fluminea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. pyramidatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. imbecillis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. teralasmus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total individuals	22	131	56	213	225	156	25	137	76
Total species	6	6	9	5	7	7	7	6	9
Menhinick's Index	1.28	0.52	1.20	0.34	0.47	0.56	1.40	0.51	1.03

(Sheet 1 of 5)

Note: Bivalves were collected by timed searches (three individuals, each for 5 min) and by having three individuals search each of three 0.25-sq m quadrats.

Table D1 (Continued)

Species	River Mile								
	72.0	72.9	73.0	73.5	73.8	74.0	74.5	75.2	76.0
P. dombeyanus	68.75	0.00	49.12	43.86	62.50	39.89	71.43	20.69	44.19
A. p. plicata	4.69	0.00	10.53	26.32	14.42	28.19	22.22	13.79	44.19
L. teres	17.19	66.67	31.58	8.77	5.77	5.32	2.38	13.79	1.74
M. nervosa	0.00	0.00	0.00	3.51	0.00	6.91	0.00	6.90	1.16
P. grandis	1.56	0.00	0.00	5.26	1.92	4.79	0.00	10.34	1.74
G. rotundatata	3.13	8.33	1.75	7.02	1.92	12.77	0.00	24.14	4.65
P. purpuratus	0.00	16.67	7.02	0.00	1.92	0.53	3.97	6.90	1.74
Q. p. pustulosa	0.00	0.00	0.00	3.51	5.77	1.06	0.00	0.00	0.00
F. flava	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A. confragosus	0.00	0.00	0.00	1.75	0.96	0.00	0.00	0.00	0.00
L. fragilis	1.56	8.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q. quadrula	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00
Q. nodulata	0.00	0.00	0.00	0.00	2.88	0.00	0.00	0.00	0.58
T. texasensis	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00
O. reflexa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. ohiensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.00
C. fluminea	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. pyramidatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. imbecillis	1.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. tetralasmus	1.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total individuals	64	12	57	57	104	188	126	29	172
Total species	8	4	5	8	11	10	4	8	8
Menhinick's Index	1.00	1.15	0.66	1.06	1.08	0.73	0.36	1.49	0.61

(Sheet 2 of 5)

Table D1 (Continued)

Species	River Mile								
	77.3	78.0	78.1	80.0	82.7	83.0	85.2	94.7	95.2
P. dombeyanus	20.00	0.00	65.71	46.67	63.38	51.06	46.19	85.90	61.00
A. p. plicata	60.00	0.00	14.29	0.00	16.90	14.89	39.83	1.28	10.00
L. teres	3.33	0.00	5.71	3.33	4.23	10.64	2.12	0.00	1.00
M. nervosa	6.67	0.00	0.00	20.00	4.23	6.38	1.27	0.00	24.00
P. grandis	3.33	0.00	7.14	10.00	5.63	4.26	1.27	0.00	1.00
G. rotundatata	3.33	0.00	0.00	0.00	0.00	2.13	0.00	2.56	1.00
P. purpuratus	3.33	66.67	2.86	16.67	2.82	6.38	0.42	5.13	0.00
Q. p. pustulosa	0.00	0.00	2.86	0.00	0.00	0.00	4.66	2.56	0.00
F. flava	0.00	0.00	0.00	0.00	0.00	0.00	2.12	0.00	0.00
A. confragosus	0.00	0.00	1.43	0.00	0.00	0.00	0.42	1.28	0.00
L. fragilis	0.00	33.33	0.00	0.00	0.00	0.00	0.85	0.00	0.00
Q. quadrula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
Q. nodulata	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00
T. texasensis	0.00	0.00	0.00	0.00	1.41	2.13	0.00	0.00	0.00
O. reflexa	0.00	0.00	0.00	0.00	0.00	2.13	0.42	0.00	0.00
P. ohiensis	0.00	0.00	0.00	3.33	1.41	0.00	0.00	0.00	0.00
C. fluminea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. pyramidatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00
U. imbecillis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. tetralasmus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total individuals	60	3	70	30	71	47	236	78	100
Total species	7	2	7	6	8	9	12	7	7
Menhinick's Index	0.90	1.15	0.84	1.10	0.95	1.31	0.78	0.79	0.70

(Sheet 3 of 5)

Table D1 (Continued)

Species	River Mile								
	96.9	98.0	98.8	101.5	109.9	114.8	117.0	123.5	128.5
P. dombeyanus	57.14	85.71	73.91	4.76	5.26	0.00	0.00	38.46	15.15
A. p. plicata	14.29	0.00	0.00	0.00	47.37	0.00	50.00	38.46	18.18
L. teres	0.00	14.29	4.35	0.00	0.00	0.00	0.00	7.69	0.00
M. nervosa	0.00	0.00	0.00	9.52	15.79	0.00	0.00	7.69	6.06
P. grandis	0.00	0.00	0.00	76.19	5.26	0.00	0.00	0.00	0.00
G. rotundatata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. purpuratus	14.29	0.00	8.70	0.00	0.00	0.00	50.00	0.00	0.00
Q. p. pustulosa	0.00	0.00	4.35	4.76	10.53	0.00	0.00	0.00	9.09
F. flava	0.00	0.00	0.00	0.00	5.26	0.00	0.00	0.00	48.48
A. confragosus	0.00	0.00	0.00	0.00	5.26	0.00	0.00	0.00	0.00
L. fragilis	14.29	0.00	4.35	0.00	0.00	0.00	0.00	0.00	0.00
Q. quadrula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.03
Q. nodulata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T. texasensis	0.00	0.00	4.35	0.00	0.00	0.00	0.00	0.00	0.00
O. reflexa	0.00	0.00	0.00	0.00	5.26	0.00	0.00	0.00	0.00
P. ohiensis	0.00	0.00	0.00	4.76	0.00	0.00	0.00	0.00	0.00
C. fluminea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.69	0.00
P. pyramidatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. imbecillis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. tetralasmus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total individuals	7	7	23	21	19	0	2	13	33
Total species	4	2	6	5	8	0	2	5	6
Menhinick's Index	1.51	0.76	1.25	1.09	1.84	0.00	1.41	1.39	1.04

(Sheet 4 of 5)

Table D1 (Concluded)

Species	River Mile								
	131.5	134.0	139.0	140.3	141.5	144.6	147.0	148.2	149.2
P. dombeyanus	44.34	73.08	0.00	0.00	35.71	50.00	10.00	0.00	8.33
A. p. plicata	10.38	14.10	27.59	0.00	14.29	0.00	60.00	0.00	37.50
L. teres	0.00	3.85	27.59	0.00	0.00	0.00	0.00	0.00	8.33
M. nervosa	13.21	0.00	0.00	0.00	0.00	0.00	0.00	25.00	8.33
P. grandis	0.94	0.00	10.34	0.00	0.00	0.00	0.00	0.00	0.00
G. rotundatata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. purpuratus	3.77	2.56	0.00	0.00	7.14	50.00	0.00	12.50	4.17
Q. p. pustulosa	4.72	3.85	3.45	0.00	28.57	0.00	0.00	25.00	12.50
F. flava	12.26	2.56	0.00	0.00	0.00	0.00	20.00	25.00	0.00
A. confragosus	1.89	0.00	20.69	0.00	0.00	0.00	0.00	0.00	4.17
L. fragilis	3.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q. quadrula	1.89	0.00	3.45	0.00	7.14	0.00	0.00	0.00	0.00
Q. nodulata	0.00	0.00	3.45	0.00	7.14	0.00	0.00	0.00	4.17
T. texasensis	0.94	0.00	0.00	0.00	0.00	0.00	0.00	12.50	0.00
O. reflexa	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33
P. ohiensis	0.00	0.00	3.45	0.00	0.00	0.00	0.00	0.00	0.00
C. fluminea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.17
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00
P. pyramidatum	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. imbecillis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. tetralasmus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total individuals	106	78	29	0	14	2	10	8	24
Total species	13	6	8	0	6	2	4	5	10
Menhinick's Index	1.26	0.68	1.49	0.00	1.60	1.41	1.26	1.77	2.04

(Sheet 5 of 5)

Table D2
Percent Occurrence of Freshwater Bivalves Collected in Shallow Water at Selected Sites in Big Sunflower River, Mississippi, in Fall of 1993

Species	River Mile								
	62.2	62.9	65.0	65.5	65.5	66.0	67.4	70.4	71.0
P. dombeyanus	50.00	100.00	33.33	91.67	100.00	91.67	41.67	83.33	58.33
A. p. plicata	8.33	50.00	33.33	58.33	58.33	50.00	25.00	33.33	33.33
L. teres	8.33	25.00	8.33	16.67	16.67	25.00	25.00	16.67	33.33
M. nervosa	0.00	0.00	0.00	0.00	8.33	8.33	0.00	33.33	16.67
P. purpuratus	0.00	0.00	8.33	0.00	0.00	0.00	8.33	0.00	0.00
P. grandis	8.33	8.33	25.00	16.67	8.33	0.00	8.33	16.67	8.33
G. rotundatata	0.00	8.33	25.00	0.00	0.00	8.33	16.67	25.00	25.00
Q. p. pustulosa	0.00	0.00	16.67	8.33	16.67	0.00	0.00	0.00	8.33
F. flava	0.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00
L. fragilis	8.33	0.00	0.00	0.00	8.33	0.00	8.33	0.00	8.33
A. confragosus	0.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q. quadrula	8.33	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00
Q. nodulata	0.00	0.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
T. texasensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33
O. reflexa	0.00	0.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
P. ohiensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. fluminea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. imbecillis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. tetralasmus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. pyramidatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total samples	12	12	12	12	12	12	12	12	12

(Sheet 1 of 5)

Note: Bivalves were collected by timed searches (three individuals, each for 5 min) and by having three individuals each search three 0.25-sq m quadrats.

Table D2 (Continued)

Species	River Mile								
	72.0	72.9	73.0	73.5	73.8	74.0	74.5	75.2	76.0
P. dombeyanus	33.33	0.00	50.00	50.00	66.67	66.67	50.00	25.00	50.00
A. p. plicata	16.67	0.00	25.00	33.33	33.33	41.67	41.67	25.00	66.67
L. teres	41.67	33.33	33.33	25.00	25.00	41.67	16.67	16.67	16.67
M. nervosa	0.00	0.00	0.00	8.33	0.00	25.00	0.00	16.67	8.33
P. purpuratus	0.00	8.33	25.00	0.00	8.33	8.33	25.00	16.67	16.67
P. grandis	8.33	0.00	0.00	16.67	16.67	33.33	0.00	16.67	8.33
G. rotundatata	16.67	8.33	8.33	16.67	16.67	41.67	0.00	41.67	41.67
Q. pustulosa	0.00	0.00	0.00	16.67	25.00	16.67	0.00	0.00	0.00
F. flava	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. fragilis	8.33	8.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A. confragosus	0.00	0.00	0.00	16.67	8.33	0.00	0.00	0.00	0.00
Q. quadrula	0.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00
Q. nodulata	0.00	0.00	0.00	0.00	16.67	0.00	0.00	0.00	8.33
T. texasensis	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00
O. reflexa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. ohiensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00
C. fluminea	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. imbecillis	8.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. tetralasmus	8.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. pyramidatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total samples	12	12	12	12	12	12	12	12	12

(Sheet 2 of 5)

Table D2 (Continued)

Species	River Mile								
	77.3	78.0	78.1	80.0	82.7	83.0	85.2	94.7	95.2
P. dombeyanus	25.00	0.00	33.33	16.67	33.33	25.00	100.00	50.00	41.67
A. p. plicata	33.33	0.00	33.33	0.00	25.00	16.67	83.33	8.33	25.00
L. teres	16.67	0.00	33.33	8.33	25.00	16.67	16.67	0.00	8.33
M. nervosa	8.33	0.00	0.00	25.00	16.67	8.33	16.67	0.00	50.00
P. purpuratus	16.67	8.33	16.67	25.00	8.33	16.67	8.33	25.0	0.00
P. grandis	16.67	0.00	25.00	16.67	8.33	8.33	25.00	0.00	8.33
G. rotundatata	16.67	0.00	0.00	0.00	0.00	8.33	0.00	16.67	8.33
Q. p. pustulosa	0.00	0.00	16.67	0.00	0.00	0.00	41.67	8.33	0.00
F. flava	0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00
L. fragilis	0.00	8.33	0.00	0.00	0.00	0.00	16.67	0.00	0.00
A. confragosus	0.00	0.00	8.33	0.00	0.00	0.00	8.33	8.33	0.00
Q. quadrula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67
Q. nodulata	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00
T. texasensis	0.00	0.00	0.00	0.00	8.33	8.33	0.00	0.00	0.00
O. reflexa	0.00	0.00	0.00	0.00	0.00	8.33	8.33	0.00	0.00
P. ohiensis	0.00	0.00	0.00	8.33	8.33	0.00	0.00	0.00	0.00
C. fluminea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. imbecillis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00
U. tetralasmus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. pyramidatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total samples	12	12	12	12	12	12	12	12	12

(Sheet 3 of 5)

Table D2 (Continued)

Species	River Mile								
	96.9	98.0	98.8	101.5	109.9	114.8	117.0	123.5	128.5
P. dombeyanus	16.67	25.00	33.33	8.33	8.33	0.00	0.00	16.67	16.67
A. p. plicata	8.33	0.00	0.00	0.00	33.3	0.00	8.33	16.67	25.00
L. teres	0.00	8.33	8.33	0.00	0.00	0.00	0.00	8.33	0.00
M. nervosa	0.00	0.00	0.00	8.33	16.67	0.00	0.00	8.33	8.33
P. purpuratus	8.33	0.00	16.67	0.00	0.00	0.00	8.33	0.00	0.00
P. grandis	0.00	0.00	0.00	8.33	8.33	0.00	0.00	0.00	0.00
G. rotundatata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q. p. pustulosa	0.00	0.00	8.33	8.33	16.67	0.00	0.00	0.00	8.33
F. flava	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00	33.33
L. fragilis	8.33	0.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
A. confragosus	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00
Q. quadrula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33
Q. nodulata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T. texasensis	0.00	0.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
O. reflexa	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00
P. ohiensis	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00	0.00
C. fluminea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00
U. imbecillis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. tetralasmus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. pyramidatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total samples	12	12	12	12	12	12	12	12	12

(Sheet 4 of 5)

Table D2 (Concluded)

Species	River Mile								
	131.5	134.0	139.0	140.3	141.5	144.6	147.0	148.2	149.2
P. dombeyanus	83.33	75.00	0.00	0.00	16.67	8.33	8.33	0.00	16.67
A. p. plicata	58.33	33.33	25.00	0.00	16.67	0.00	33.33	0.00	33.33
L. teres	0.00	16.67	33.33	0.00	0.00	0.00	0.00	0.00	8.33
M. nervosa	58.33	0.00	0.00	0.00	0.00	0.00	0.00	16.67	16.67
P. purpuratus	25.00	16.67	0.00	0.00	8.33	8.33	0.00	8.33	8.33
P. grandis	8.33	0.00	16.67	0.00	0.00	0.00	0.00	0.00	0.00
G. rotundatata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Q. p. pustulosa	41.67	16.67	8.33	0.00	16.67	0.00	0.00	16.67	8.33
F. flava	75.00	8.33	0.00	0.00	0.00	0.00	16.67	8.33	0.00
L. fragilis	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A. confragosus	16.67	0.00	25.00	0.00	0.00	0.00	0.00	0.00	8.33
Q. quadrula	16.67	0.00	8.33	0.00	8.33	0.00	0.00	0.00	0.00
Q. nodulata	0.00	0.00	8.33	0.00	8.33	0.00	0.00	0.00	8.33
T. texasensis	8.33	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00
O. reflexa	8.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67
P. ohiensis	0.00	0.00	8.33	0.00	0.00	0.00	0.00	0.00	0.00
C. fluminea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.33
L. hydiana	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.00	0.00
U. imbecillis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. declivis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. tetralasmus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. pyramidatum	8.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total samples	12	12	12	12	12	12	12	12	12

(Sheet 5 of 5)

Table D3
Percent Abundance and Percent Occurrence of Freshwater Bivalves at All Shallow-Water Sites Between River Miles 62 and 150 (Summary of Tables D1 and D2)

Species	Percent Abundance	Percent Occurrence
P. dombeyanus	56.95	37.78
A. p. plicata	21.29	25.56
L. teres	4.86	14.07
M. nervosa	3.57	8.52
P. grandis	2.82	7.78
G. rotundatata	2.45	7.78
P. purpuratus	2.01	7.96
Q. p. pustulosa	1.97	7.22
F. flava	1.43	4.07
L. fragilis	0.54	2.78
A. confragosus	0.54	2.59
Q. quadrula	0.34	1.85
Q. nodulata	0.31	1.48
O. reflexa	0.24	1.30
T. texasensis	0.24	1.30
P. ohiensis	0.17	0.93
L. hydiana	0.07	0.37
C. fluminea	0.07	0.37
U. declivis	0.03	0.19
U. imbecillis	0.03	0.19
P. pyramidatum	0.03	0.19
U. tetralasmus	0.03	0.19
Total individuals	2,941	
Total species	23	
Total samples	540	
Total sites	45	

Table D4
Density of Freshwater Mussels and Collection Rate at a Series of Sites Upriver of Lock and Dam 1, Big Sunflower River, September - October 1993

Site	River Mile	No./0.25 sq m	No./sq m	Number Collected/min	Miles From Last Site
A	63.2	4.89	19.56	6.67	
D	63.9	2.56	10.24	7.20	0.7
E1	66.0	1.33	5.32	3.40	2.1
E2	66.0	0.33	1.32	4.00	0.0
E3	66.0	0.33	1.32	2.80	0.0
F1	66.5	1.00	4.00	9.20	0.5
F2	66.5	4.67	18.68	16.20	0.0
F3	66.5	5.33	21.32	10.60	0.0
G1	66.5	3.33	13.32	13.80	0.0
G2	66.5	2.00	8.00	8.80	0.0
G3	66.5	5.33	21.32	16.00	0.0
H1	67.0	3.33	13.32	6.60	0.5
H2	67.0	1.00	4.00	9.60	0.0
H3	67.0	1.67	6.68	11.40	0.0
I1	68.4	0.33	1.32	1.20	1.4
I2	68.4	0.67	2.68	1.00	0.0
I3	68.4	0.00	0.00	2.20	0.0
J1	71.4	2.00	8.00	9.20	3.0
J2	71.4	1.00	4.00	4.40	0.0
J3	71.4	2.33	9.32	10.60	0.0
K1	72.0	0.67	2.68	6.40	0.6
K2	72.0	1.00	4.00	4.20	0.0
K3	72.0	0.67	2.68	3.20	0.0
L1	73.0	1.67	6.67	4.00	1.0
L2	73.0	1.00	4.00	3.60	0.0

(Sheet 1 of 4)

Note: For most locations, density data were obtained by having each individual search the area within three 0.25-sq m quadrats. For example, at Site "E," three individuals (E1, E2, and E3) each collected from three quadrats. Individual E1 obtained a mean of 5.32 mussels in the three quadrats. Collection rate was obtained by having each individual (E1, E2, and E3) search for freshwater mussels for 5 min. Individual E1 collected at a rate of 3.40 individuals/ minute.

Table D4 (Continued)

Site	River Mile	No./0.25 sq m	No./sq m	Number Collected/min	Miles From Last Site
L3	73.0	0.00	0.00	3.60	0.0
M1	73.9	0.33	1.33	0.60	0.9
M2	73.9	0.33	1.33	0.60	0.0
M3	73.9	0.00	0.00	0.80	0.0
N1	74.0	1.33	5.33	3.40	0.1
N2	74.0	0.33	1.33	3.00	0.0
N3	74.0	1.00	4.00	3.40	0.0
P1	74.5	1.00	4.00	5.20	0.5
P2	74.5	0.33	1.33	3.20	0.0
P3	74.5	0.67	2.67	1.80	0.0
O1	74.8	0.67	2.67	6.40	0.3
O2	74.8	1.33	5.33	4.60	0.0
O3	74.8	1.00	4.00	8.00	0.0
Q1	75.0	1.33	5.33	12.00	0.2
Q2	75.0	1.00	4.00	9.80	0.0
Q3	75.0	2.33	9.33	13.00	0.0
R1	75.5	2.67	10.67	6.80	0.5
R2	75.5	1.67	6.67	9.00	0.0
R3	75.5	1.00	4.00	6.20	0.0
S1	76.2	0.33	1.33	2.20	0.7
S2	76.2	0.67	2.67	1.20	0.0
S3	76.2	0.33	1.33	1.60	0.0
T1	77.0	2.00	8.00	15.60	0.8
T2	77.0	1.00	4.00	10.00	0.0
T3	77.0	2.33	9.33	5.60	0.0
U1	78.3	0.00	0.00	0.40	1.3
U2	78.3	0.00	0.00	3.00	0.0
U3	78.3	3.00	12.00	6.80	0.0
V1	79.0	0.00	0.00	0.40	0.7
V2	79.0	0.00	0.00	0.20	0.0
V3	79.0	0.00	0.00	0.00	0.0

Table D4 (Continued)

Site	River Mile	No./0.25 sq m	No./sq m	Number Collected/min	Miles From Last Site
AA1	79.1	3.67	14.68	15.40	0.1
AA2	79.1	6.33	25.32	14.00	0.0
AA3	79.1	5.33	21.32	8.60	0.0
W1	81.0	0.33	1.33	3.40	1.9
W2	81.0	0.00	0.00	1.40	0.0
W3	81.0	0.00	0.00	1.00	0.0
X1	83.7	0.00	0.00	6.60	2.7
X2	83.7	0.00	0.00	2.80	0.0
X3	83.7	1.00	4.00	4.20	0.0
Y1	84.0	0.33	1.32	6.20	0.3
Y2	84.0	0.00	0.00	2.80	0.0
Y3	84.0	0.00	0.00	0.20	0.0
Z1	86.2	0.67	2.67	6.60	2.2
Z2	86.2	0.00	0.00	4.40	0.0
Z3	86.2	0.67	2.67	2.20	0.0
AB1	95.7	1.33	5.32	4.60	9.5
AB2	95.7	1.33	5.32	5.40	0.0
AB3	95.7	0.00	0.00	3.80	0.0
AC1	96.2	1.67	6.68	5.60	0.5
AC2	96.2	1.00	4.00	8.80	0.0
AC3	96.2	0.00	0.00	4.00	0.0
AD1	97.9	0.00	0.00	0.00	1.7
AD2	97.9	0.00	0.00	0.80	0.0
AD3	97.9	0.00	0.00	0.60	0.0
AE1	99.0	0.33	1.32	0.20	1.1
AE2	99.0	0.00	0.00	0.80	0.0
AE3	99.0	0.33	1.32	0.00	0.0
AF1	99.8	0.33	1.32	2.20	0.8
AF2	99.8	0.00	0.00	1.40	0.0
AF3	99.8	0.00	0.00	0.80	0.0

(Sheet 3 of 4)

Table D4 (Concluded)

Site	River Mile	No./0.25 sq m	No./sq m	Number Collected/min	Miles From Last Site
AU	102.5	0.00	0.00	1.40	2.7
AT	110.9	0.33	1.32	1.07	8.4
AS	115.8	0.00	0.00	0.00	4.9
AR	118.0	0.11	0.44	0.07	2.2
AQ	124.5	0.00	0.00	0.80	6.5
AP	129.5	0.56	2.24	1.87	5.0
AO	132.5	5.56	22.24	3.67	3.0
AN	135.0	1.78	7.12	4.13	2.5
AM	140.0	0.44	1.76	1.67	5.0
AL	141.3	0.00	0.00	0.00	1.3
AK	142.5	0.11	0.44	0.87	1.2
AJ	145.6	0.00	0.00	0.13	3.1
AI	148.0	0.11	0.44	0.53	2.4
AH	149.2	0.11	0.44	0.47	1.2
AG	150.2	0.78	3.12	1.13	1.0

(Sheet 4 of 4)

Table D5
Summary Statistics for Bivalve Samples Collected in Two Reaches of Big Sunflower River, September - October 1993

Parameter	RMs 62.2 - 83.0		RMs 85.2 - 149.2	
	No./sq m	No./min	No./sq m	No./min
Minimum	0.00	0.00	0.00	0.00
Maximum	25.32	16.20	22.24	8.80
Range	25.32	16.20	22.24	8.80
Mean	5.50	5.75	2.13	2.12
Standard deviation	6.15	4.40	4.09	2.21
Standard error	0.75	0.53	0.71	0.38
Number of samples	68	68	33	33

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13. ABSTRACT *(Maximum 200 words)*

A survey to assess community characteristics, density, population demography of dominant species and the presence of rare or endangered species of mussels (Family: Unionidae) was conducted in the Big Sunflower River, September - October 1993. Results will be used to assess the economic value of mussels and to determine the environmental effects of proposed maintenance dredging. Studies were conducted at four beds downriver of Lock and Dam 1 (River Mile (RM) 62 - RM 33.7) and along a river reach upriver of the dam (RM 62.2 - RM 149.2). Downriver of the dam, the substratum at two beds consisted of sand and gravel; one was characterized by clay and sand; and one was composed of silt and sand. Shells of many specimens were eroded and difficult to identify. Upriver of the dam (RM 62.2 - RM 149.2), conditions were more depositional than downriver; fine-grain silt 50 to 70 cm deep was common along the shore. No endangered species were found in the project area, although *Pleurobema pyramidatum*, which was uncommon in the project area, is a candidate for inclusion on the Federal list of endangered species.

At the four beds downriver of the dam, the fauna was dominated by the commercially valuable threeridge (*Amblema plicata plicata*) (49.1 to 90.0 percent), followed by the pimpleback (*Quadrula pustulosa pustulosa*) (2.0 to

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19.4 percent), and the bankclimber (*Plectomerus dombeyanus*) (3.5 to 29.0 percent). Species richness at these beds (9 to 12) and species diversity (H', 0.49 to 1.46) were low. Mean density (individuals/square meter) was high and ranged from 28.6 (±2.8, ±Standard Error) to 235.0 (±16.0) and mean biomass (grams/square meter) ranged from 6,590.8 (±636.1) to 52,250.1 (±3,284.8). There was virtually no evidence of recent recruitment for any species; less than 1 percent were less than 30 mm in total length.

A greater number of bivalve species (23) were found at depositional sites upriver of abandoned Lock and Dam 1 than downriver of the dam (20). At RM 66.0, *Plectomerus dombeyanus* dominated (71 percent) shallow water (0.6 m deep) along the shore but was uncommon in the channel (1.8 m deep). In the main channel, *Quadrula pustulosa pustulosa* (4.8 percent) and *Megalonaias nervosa* (17.7 percent) were fairly common, although both were either absent or uncommon in shallow water along the shore. Mean density and collection rate (mussels collected/minute) was 5.5 ± 0.75 and 5.7 ± 0.53 between RM 62.2 and RM 83.0. Between RM 85.2 and RM 149.2, density and collection rate were less than in the lower reach; 2.13 ± 0.71 individuals/square meter and 2.2 ± 0.38 individuals were collected/minute.

Marketable sizes of commercially valuable species in the project area have been tentatively established. If the minimum marketable size of the threeridge was 2-5/8 (2.625) in. high (equal to about 94.57 mm long), then approximately 36.0 percent of the population would be harvestable (by fall 1993). Shells of the commercially valuable threeridge have a greater length:height ratio (are more narrow) than specimens from a bed in the upper Mississippi River. If the minimum marketable size of *M. nervosa* was 3.25 in. high (about 116.4 mm long), then 84.42 percent of the population could be harvested. It was estimated that 1.39 and 1.34 million pounds of threeridge and washboard are marketable. At a price of $1 per pound, these two species would have a total value of approximately $2.7 million dollars. This value considers only specimens of marketable size in 1994.

Maintenance dredging and commercial shell harvest could negatively affect common and uncommon species in the Big Sunflower River. The lack of recent recruitment, dominance of a single species, and low species richness make this community particularly vulnerable. Upriver of the dam, dredging should be restricted to the channel to protect valuable populations along the shore. The beds downriver of the dam could be partially protected by restricting dredging to one bank. Commercial harvest should be carefully regulated and monitored, and selected reaches should be set aside as sanctuaries. The long-term survival of this resource could be ensured by regular monitoring and careful adherence to a well-designed dredging and commercial harvest plan.